The mechanical engineer's pocket-book of tables, ...

Daniel Kinnear Clark

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THE

ECHANICAL ENGINEER'S POCKET-BOOK

OF

Tables, Formulæ, Rules, and Data

A HANDY BOOK OF REFERENCE FOR
DAILY USE IN ENGINEERING PRACTICE

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BY

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"RAILWAY MACHINERY;" "TRAMWAYS;" "THE STEAM ENGINE;"
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PREFACE.

MANY works of the POCKET-BOOK class have already een published for the use of professional men ; but ot one of those with which I am acquainted has been ompiled expressly with a view to the requirements f the Mechanical Engineer.

This POCKET-BOOK has accordingly been prepared or the purpose of shortening the calculations and ther intricate mental operations which are amongst he daily recurring needs of mechanical men. To meet such needs, there will be found in the following pages about 350 Tables of results of calculations, relating to the principal branches of mechanical practice, which have either been compiled anew, or drawn from various sources. There are, in addition, about 500 Formulæ and Rules, with Data of general utility, classified for ready reference. By their aid, many a weary search in larger and more ambitious books may be dispensed with, and the labour of calculation greatly abridged, or even entirely avoided.

I do not lay especial claim in these pages to originality, for much of the matter of the book is necessarily common property. I have, nevertheless, contributed many original tables, formulæ, and data, herein published for the first time. And with regard to all matter in the work, I have spared no pains, on the one hand, to select such questions as the mechanical engineer would probably most desire to find elucidated ; and on the other, to draw my material from the best and most trustworthy sources.

Besides the usual indispensable mathematical tables, and rules for measurement of surfaces and solids, full tables of English weights and measures, with French metric equivalents, are given; tables of French metric weights and measures, with equivalent English values, are also given.

Many useful tables are given of the weights and strength of bars, sheets, beams, joists, girders, tubes, pipes, bolts and nuts, cylinders, nails, chains, and other manufactured pieces. For the strength of materials, a variety of experimental evidence is given, with many new formulæ and tables. Heat and its applications have been fully considered in various aspects. The best proportions of steam engines, simple and compound, are discussed; together with pumping engines, water power, and compressed-air power.

I am indebted to Mr. H. R. Kempe, A.M.I.C.E., for his assistance in the preparation of the section on Electrical Engineering; and in various sections acknowledgment will be found duly made of my indebtedness to other authorities.

I am in hopes that the variety of matter here presented will meet all reasonable requirements of practical men in such a work, and enable them to dispense very largely with exterior aid.

At the same time, I shall be glad to avail myself of the hints or suggestions of mechanical men using the book, with a view to improve and to perfect its contents; and I shall receive with pleasure communications which may be made to me from any quarter with that object.

D. K. CLARK.

LONDON, *November*, 1891.

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THE
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MATHEMATICAL TABLES.

Introduction to the Tables.

TABLE 1.—*Circumferences and Areas of Circles, Squares, Cubes, Square Roots, and Cube Roots of Numbers, from* 1 *to* 1000.

THE powers and roots of numbers may be calculated by means of logarithms ; but this table will considerably economise calculation.

The columns of squares and cubes may be utilised inversely, for finding in the first column the roots of numbers contained in those columns.

The columns of square roots and cube roots, also, may be utilised for finding, in the first column, the squares and cubes of numbers containing decimals in those columns.

Further, the squares in the fourth column are the fourth powers of the square roots in the sixth column.

Again, any number in the first column may be conceived to consist of an integer and decimals, when the corresponding square or cube, with a decimal point suitably placed, will be the square or the cube of the assumed number. For example, suppose that the number 186 represents 18·6, or 1·86, or ·186, the square will contain two, or four, or six places of decimals respectively ; and the cube will contain three, or six, or nine places of decimals respectively. Thus,—

Number.	Square.	Cube.
186	34,596	6,434,856
18·6	345·96	6,434·856
1·86	3·4596	6·434856
·186	·034596	·006434856

The number of places of decimals is fixed in each instance according to the common rule of twice the number of decimal places in the original number for a square, and three times the number in the original for a cube.

TABLE 2.—*Diameter, Circumference, and Area of Circles, advancing by Vulgar Fractions, from* $\frac{1}{16}$ *to* 120.

The diameters specifically represent lengths in inches and parts of inches. But they may represent values in any other units, as feet or yards.

TABLE 3.—*Reciprocals of Numbers, from* 1 *to* 1000.

The reciprocal of a number is the quotient obtained by dividing 1 by the given number.

The product of any number with its reciprocal is equal to 1. Hence a ready means of checking the accuracy of any reciprocal, which when multiplied by its number should give a quotient of 1.

The reciprocal of a vulgar fraction is equal to the quotient of the denominator by the enumerator. Thus the reciprocal of $\frac{1}{2}$ is equal to $\left(\frac{2}{1} =\right)$ 2. Or, the vulgar fraction may be reduced to a decimal form, and the decimal value divided into 1. Thus $\frac{1}{2} = \cdot 5$, and $1 \div \cdot 5 = 2$.

TABLE 4.—*Logarithms of Numbers, from* 1 *to* 10,000.

Logarithms are designed to abbreviate calculations involving multiplication and division of numbers, by the substitution of calculations by addition and subtraction respectively. Logarithms consist of integers and decimals, and they are given in Table 4 for numbers ranging from 1 to 10,000. The integers or indices, as they are called, are, except in the small preliminary tablet, omitted in the table, for the sake of brevity, but chiefly for the sake of clearness and simplicity. The decimal values of the logarithms are given to six places. The integer or index of each logarithm is less by 1 than the number of places in the integer of the number; and if the number contain only decimals, the index is equal to the number of cyphers next the decimal point, plus 1. The index in this case is negative, and is so distinguished by the sign minus, −, written over it. The adjustment of the integer of a logarithm to the composition of the given number is exemplified in the following series, in which the same number is repeated several times, having the decimal point shifted regularly by one digit towards the left:—

5314	3·725422
531·4	2·725422
53·14	1·725422
5·314	0·725422
·5314	$\bar{1}$·725422
·05314	$\bar{2}$·725422
·005314	$\bar{3}$·725422

To find the logarithm of a number. If the number contain only one or two digits, look for it in the columns marked N in the preliminary tablet, and find the logarithm next to it, or, look for the number in the body of the table, with one, or two, cyphers following it; and the decimal part of the logarithm stands next to the number, in the column headed 0. For example, the decimal part of the logarithm of 5, ·698970, is in the column next to 500, in page 63 of the table; corresponding to the single digit in the integer, the integral figure of the logarithm is 0, and the complete logarithm is 0·698970. For 50, the logarithm is 1·698970; and for 500, the logarithm is 2·698970; but for ·5, the logarithm is $\bar{1}$·698970.

In short, if the given number consist of one, two, or three digits, the decimal part of its logarithm is found in the column headed 0. If the number consist of four digits, look for the first, second, and third in the column N, and the fourth in the row of headings or footings at the top or the bottom of the table; and the logarithmic decimal is found opposite the number in the marginal column, and below or above the fourth. If the number consist of five or more digits, the logarithm for the first to the fourth digits being found as above, multiply the corresponding difference in the last column, D, by the remaining digits, and divide by 10 if there be only one digit more, by 100 if there be ten more, and so on. Add the quotient to the logarithm already obtained, to give the logarithm required. For example, to find the logarithm of 62·355. The decimal part of the logarithm of 6235 is ·794836, and the corresponding difference ($70 \times 5 \div 10 =$) 35, is to be added, thus—

0·794836
35

0·794871 the completed logarithm.

Conversely, the number for a given logarithm is found by searching for the decimal part of the logarithm. If it be found exactly or within a few units of the right-hand digit, note the first, second, and third digits of the required number in the column N, and the fourth digit at the top or the bottom, above or below the decimal; and place the decimal point. If the logarithm differ materially from the nearest in the table, find the number for the next less logarithm in the table, to give the first, second, third, and fourth digits. To find the fifth and, if necessary, the sixth digit, subtract the tabulated logarithm from the given logarithm, add two cyphers, and divide by the difference found in column D in a line with the logarithm. Annex the quotient to the four digits already found, and place the decimal point. For example, to find the number represented by the logarithm 0·497151. The nearest less logarithm in the table is 0·497068, for the number 3141. Subtracting this logarithm from that, thus—

$$\begin{array}{r} 0{\cdot}497151 \\ 0{\cdot}497068 \\ \hline 83 \end{array}$$

add two cyphers to the difference, making 8300, and divide by 138, the difference in column D. Then 8300 ÷ 138 = 60, and annexing 60 to 3141, the number is 314160. Placing the decimal point, the completed number is 3·14160, or 3·1416.

To multiply two or more numbers together, add together their logarithms. The sum is the logarithm of the product. To divide one number by another, subtract the logarithm of this from the logarithm of that; the number corresponding to the difference is the quotient.

To find any power of a given number, multiply the logarithm of the number by the exponent of the power. The product is the logarithm of the power.

To find any root of a given number, divide the logarithm of the number by the index of the root.

To find the reciprocal of a given number, subtract the decimal part of the logarithm of the number from 0·000000; add 1 to the index of the logarithm and change the sign of the index. For example, to find the reciprocal of 350:—

$$\begin{array}{lr} & 0{\cdot}000000 \\ \text{log. } 350 \quad . \quad . & 2{\cdot}544068 \\ \hline & 3{\cdot}455932 = \text{log. } {\cdot}002857. \end{array}$$

Conversely, to find the reciprocal of the decimal ·002857:—

$$\begin{array}{lr} & 0{\cdot}000000 \\ \text{log. } {\cdot}002857 \quad . & 3{\cdot}455932 \\ \hline & 2{\cdot}544068 = \text{log. } 350. \end{array}$$

These two calculations afford examples of negative indices. In the first, the logarithm of 350 has the index 2, or + 2, the sign of which is changed for subtraction, making – 2. In deducting the digit 5, the first decimal, from 0, 1 is carried to it from the previous subtraction, making 6, which deducted from 10 leaves 4. Carrying 1, – 2 and – 1 make – 3, which is the index of the remainder, $\bar{3}$·455932, the logarithm of ·002857.

In the second calculation above, in deducting the first decimal, 4 augmented by 1 carried, or 5, from 10, there remains 5, the first decimal in the remainder; and 1 is carried to the index place. But, first, the sign of the index is changed, and the index becomes + 3; and from this the carried 1 is deducted, leaving + 2 the index of the remaining logarithm of 350.

To add together two negative indices, they are simply added and the negative sign placed over the sum, thus $\bar{3} + \bar{2} = \bar{5}$. In the addition together of a positive index and a negative index, their difference is the sum, bearing the sign of the greater additive; thus $3 + \bar{2} = 1$; or $2 + \bar{3} = \bar{1}$. For example:—

$$\begin{aligned} \text{log. } 3442 &= 3{\cdot}536811 \\ \text{log. } {\cdot}02801 &= 2{\cdot}447313 \\ \hline \text{log. } 96{\cdot}41 &= 1{\cdot}984124 \end{aligned}$$

To subtract a negative index, change the sine and add. Thus, to subtract $\bar{2}$ from $\bar{3}$, there is $3 + 2 = \bar{1}$; but this may be done simply thus $\bar{3} - \bar{2} = \bar{1}$. Again, 3 from 2 = 3 + 2 = 5. To subtract a positive index from a negative index, change the positive sign to negative and add; thus, 3 from $\bar{5} = \bar{3} + \bar{5} = \bar{8}$.

To find a root of a given number. Divide the logarithm of the number by the exponent of the root: the quotient is the logarithm of the root. If the index be negative, and is divisible without a remainder, the quotient of the index is negative. If it be not so divisible, add to it so much in the negative as will make it divisible, and divide it, to give the index, which is negative; prefix an equal quantity to the decimal part of the logarithm, and divide separately. The two quotients together make the logarithm of the root. For example, to find the square root of 1849:—

$$\begin{aligned} \text{log. } 1849 &= 3{\cdot}266937 \\ \text{divided by } 2 &= 1{\cdot}633469 = \text{log. } 43. \end{aligned}$$

To find the fourth root of ·00578 :—

log. ·00578 = $\bar{3}\cdot761928$
divide by 4, say $\bar{4} + 1\cdot761928$
giving $\bar{1}\cdot440482$ = log. ·2757.

It is, in ordinary practice, for the most part, unnecessary to note the indices of logarithms, as the numbers are mostly sufficiently indicated without the indices. Besides, in many cases, rough approximations suffice, particularly where numbers are expressed wholly or partly in decimals.

TABLE 5.—*Hyperbolic Logarithms of Numbers from* 1·01 *to* 20.

The table of hyperbolic logarithms is useful chiefly in calculations of the work of steam by expansion. The numbers range from 1·01 to 20. Hyperbolic, or Neperian, logarithms, are calculated by multiplying the common logarithms of numbers, as given in Table 4, by the constant multiplier 2·302585.

TABLE 6.—*Sines and Cosines of Angles from* 0° to 90°.

The tabulated values are the proportional values when the length of the radius of the circle is taken as 1. When the actual length of the radius is given, the actual length of any sine or cosine is found by multiplying the tabular value by the length of the radius.

The table is arranged so that each value signifies the sine of an angle and the cosine of its complement for 90 degrees. The values are given for angles advancing by half a degree. The values for intermediate angles, sufficiently near exactness for most purposes, can be found by interpolation in simple proportion. By an inverse operation, the angle may be found for any given sine or cosine not given in the table.

TABLE 7.—*Tangents and Cotangents of Angles from* 0° *to* 90°.

The values are, like those of the sines and cosines, proportional values, the radius being taken as 1. The actual values of the tangents and cotangents are calculated by multiplying the actual length of the radius by the corresponding tabular value of the tangent or the cotangent.

Each tabular value is that of the tangent of an angle, and also that of the cotangent of the complementary angle. The values are given for angles advancing by half a degree ; and values for intermediate angles may be found by interpolation. Inversely, the angle may be found for any given tangent or cotangent not found in the table.

TABLE 8.—*Lengths of Circular Arcs, from 1° to 180°.*

The lengths of circular arcs of which the magnitudes in degrees are given, are stated in proportion to the length of the radius, taken as 1. The actual length of the arc is found by multiplying the actual length of the radius by the tabular length corresponding to the number of degrees in the arc.

TABLE 9.—*Lengths of Circular Arcs, up to a Semicircle, when the Chord is given.*

In this table, the length of the arc is given proportionally to the length of the chord, which is taken as 1. The heights of the arcs in the table are the quotients arising by dividing the actual heights by the actual lengths of the chords, and are the ratios of the heights to the chords.

To use the table, therefore, divide the height of the arc by the length of the chord; find the quotient in the columns of heights in the table, and multiply the corresponding tabular length of the arc by the actual length of the chord. The product is the length of the arc.

TABLE 10.—*Areas of Circular Segments.*

The tabular areas of circular segments are in proportional superficial measure, corresponding to the length of the diameter, which is taken as 1. The tabular heights of the segments are the quotients of the heights divided by the diameters; the relative areas are given in the columns of areas.

To use the table, divide the actual height by the actual diameter, find the quotient in the columns of heights; and multiply the corresponding tabular area by the square of the actual length of the diameter. The product is the actual area.

TABLE 11.—*Lengths of Semi-Elliptic Arcs up to a Semi-Circle.*

This table has been calculated by means of Mr. Trautwine's formula. In the columns of heights are the ratios of the rise to the span or chord of an elliptic arc. To use the table, divide the given rise by the chord, and find the quotient in the columns of heights. Next to this quotient, in the adjoining column, is a multiplier, which when multiplied by the actual length of the span, gives the length of the arc.

TABLE 1.—NUMBERS (FROM 1 TO 1,000), OR DIAMETERS OF CIRCLES, CIRCUMFERENCES, AREAS, SQUARES, CUBES, SQUARE ROOTS, AND CUBE ROOTS.*

No. or Diam.	Circumference.	Circular Area.	Square.	Cube.	Square Root.	Cube Root.
1	3·1416	0·7854	1	1	1·000	1·000
2	6·2832	3·1416	4	8	1·414	1·259
3	9·4248	7·0686	9	27	1·732	1·442
4	12·57	12·57	16	64	2·000	1·587
5	15·71	19·63	25	125	2·236	1·709
6	18·85	28·27	36	216	2·449	1·817
7	21·99	38·48	49	343	2·645	1·912
8	25·13	50·27	64	512	2·828	2·000
9	28·27	63·62	81	729	3·000	2·080
10	31·42	78·54	100	1,000	3·162	2·154
11	34·56	95·03	121	1,331	3·316	2·223
12	37·70	113·10	144	1,728	3·464	2·289
13	40·84	132·73	169	2,197	3·605	2·351
14	43·98	153·94	196	2,744	3·741	2·410
15	47·12	176·71	225	3,375	3·872	2·466
16	50·26	201·06	256	4,096	4·000	2·519
17	53·41	226·98	289	4,913	4·123	2·571
18	56·55	254·47	324	5,832	4·242	2·620
19	59·69	283·53	361	6,859	4·358	2·668
20	62·83	314·16	400	8,000	4·472	2·714
21	65·97	346·36	441	9,261	4·582	2·758
22	69·11	380·13	484	10,648	4·690	2·802
23	72·26	415·48	529	12,167	4·795	2·843
24	75·40	452·39	576	13,824	4·898	2·884
25	78·54	490·87	625	15,625	5·000	2·924
26	81·68	530·93	676	17,576	5·099	2·962
27	84·82	572·56	729	19,683	5·196	3·000
28	87·96	615·75	784	21,952	5·291	3·036
29	91·11	660·52	841	24,389	5·385	3·072
30	94·25	706·86	900	27,000	5·477	3·107
31	97·39	754·77	961	29,791	5·567	3·141
32	100·53	804·25	1,024	32,768	5·656	3·174
33	103·67	855·30	1,089	35,937	5·744	3·207
34	106·81	907·92	1,156	39,304	5·830	3·239
35	109·96	962·11	1,225	42,875	5·916	3·271
36	113·10	1017·88	1,296	46,656	6·000	3·301
37	116·24	1075·21	1,369	50,653	6·082	3·332
38	119·38	1134·11	1,444	54,872	6·164	3·361
39	122·52	1194·59	1,521	59,319	6·244	3·391

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* See Introduction, *ante*, p. 1.

No. or Diam.	Circumference.	Circular Area.	Square.	Cube.	Square Root.	Cube Root.
40	125·66	1256·64	1,600	64,000	6·326	3·419
41	128·80	1320·25	1,681	68,921	6·403	3·448
42	131·95	1385·44	1,764	74,088	6·480	3·476
43	135·09	1452·20	1,849	79,507	6·557	3·503
44	138·23	1520·53	1,936	85,184	6·633	3·530
45	141·37	1590·43	2,025	91,125	6·708	3·556
46	144·51	1661·90	2,116	97,336	6·782	3·583
47	147·65	1734·94	2,209	103,823	6·855	3·608
48	150·80	1809·56	2,304	110,592	6·928	3·634
49	153·94	1885·74	2,401	117,649	7·000	3·659
50	157·08	1963·50	2,500	125,000	7·071	3·684
51	160·22	2042·82	2,601	132,651	7·141	3·708
52	163·36	2123·72	2,704	140,608	7·211	3·732
53	166·50	2206·18	2,809	148,877	7·280	3·756
54	169·65	2290·22	2,916	157,464	7·348	3·779
55	172·79	2375·83	3,025	166,375	7·416	3·802
56	175·93	2463·01	3,136	175,616	7·483	3·825
57	179·07	2551·76	3,249	185,193	7·549	3·848
58	182·21	2642·08	3,364	195,112	7·615	3·870
59	185·35	2733·97	3,481	205,379	7·681	3·892
60	188·50	2827·43	3,600	216,000	7·745	3·914
61	191·64	2922·47	3,721	226,981	7·810	3·936
62	194·78	3019·07	3,844	238,328	7·874	3·957
63	197·92	3117·25	3,969	250,047	7·937	3·979
64	201·06	3216·99	4,096	262,144	8·000	4·000
65	204·20	3318·31	4,225	274,625	8·062	4·020
66	207·34	3421·19	4,356	287,496	8·124	4·041
67	210·49	3525·65	4,489	300,763	8·185	4·061
68	213·63	3631·68	4,624	314,432	8·246	4·081
69	216·77	3739·28	4,761	328,509	8·306	4·101
70	219·91	3848·45	4,900	343,000	8·366	4·121
71	223·05	3959·19	5,041	357,911	8·426	4·140
72	226·19	4071·50	5,184	373,248	8·485	4·160
73	229·34	4185·39	5,329	389,017	8·544	4·179
74	232·48	4300·84	5,476	405,224	8·602	4·198
75	235·62	4417·86	5,625	421,875	8·660	4·217
76	238·76	4536·46	5,776	438,976	8·717	4·235
77	241·90	4656·63	5,929	456,533	8·744	4·254
78	245·04	4778·36	6,084	474,552	8·831	4·272
79	248·19	4901·67	6,241	493,039	8·888	4·290
80	251·33	5026·55	6,400	512,000	8·944	4·308
81	254·47	5153·00	6,561	531,441	9·000	4·326

No. or Diam.	Circumference.	Circular Area.	Square.	Cube.	Square Root	Cube Root.
82	257·61	5281·02	6,724	551,368	9·055	4·344
83	260·75	5410·61	6,889	571,787	9·110	4·362
84	263·89	5541·77	7,056	592,704	9·165	4·379
85	267·03	5674·50	7,225	614,125	9·219	4·396
86	270·18	5808·80	7,396	636,056	9·273	4·414
87	273·32	5944·68	7,569	658,503	9·327	4·431
88	276·46	6082·12	7,744	681,472	9·380	4·447
89	279·60	6221·14	7,921	704.969	9·433	4·461
90	282·74	6361·73	8,100	729.000	9·486	4·481
91	285·88	6503·88	8,281	753,571	9·539	4·497
92	289·03	6647·61	8,464	778,688	9·591	4·514
93	292·17	6792·91	8,649	804,357	9·643	4·530
94	295·31	6939·78	8,836	830,584	9·695	4·546
95	298·45	7088·22	9,025	857.375	9·746	4·562
96	301·59	7238·23	9,216	884.736	9·797	4·578
97	304·73	7389·81	9,409	912,673	9·848	4·594
98	307·88	7542·96	9,604	941,192	9·899	4·610
99	311·02	7697·69	9,801	970,299	9·949	4·626
100	314·16	7853·98	10,000	1,000,000	10·000	4·641
101	317·30	8011·85	10.201	1,030,301	10·049	4·657
102	320·44	8171·28	10.404	1.061.208	10·099	4·672
103	323·58	8332·29	10,609	1,092,727	10·148	4·687
104	326·73	8494·87	10,816	1,124.864	10·198	4·702
105	329·87	8659·01	11,025	1,157,625	10·246	4·717
106	333·01	8824·73	11,236	1,191,016	10·295	4·732
107	336·15	8992·02	11,449	1,225.043	10·344	4·747
108	339·29	9160·88	11,664	1,259,712	10·392	4,762
109	342·43	9331·32	11,881	1,295,029	10·440	4·776
110	345·57	9503·32	12,100	1,331,000	10·488	4·791
111	348·72	9676·89	12,321	1,367,631	10·535	4·805
112	351·86	9852·03	12,544	1,404,928	10·583	4·820
113	355·00	10028·75	12,769	1,442.897	10·630	4·834
114	358·14	10207·03	12,996	1,481.544	10·677	4·848
115	361·28	10386·89	13.225	1,520.875	10·723	4·862
116	364·42	10568·32	13,456	1,560,896	10·770	4·876
117	367·57	10751·32	13,689	1,601.613	10·816	4·890
118	370·71	10935·88	13.924	1,643,032	10·862	4·904
119	373·85	11122·02	14.161	1,685.159	10·908	4·918
120	376·99	11309·73	14,400	1,728,000	10·954	4·932
121	380·13	11499·01	14,641	1,771,561	11·000	4·946
122	383·27	11689·87	14,884	1,815,848	11·045	4·959
123	386·42	11882·29	15,129	1,860,867	11·090	4·973

No. or Diam.	Circumference.	Circular Area.	Square.	Cube.	Square Root.	Cube Root.
124	389·56	12076·28	15,376	1,906,624	11·135	4·986
125	392·70	12271·85	15,625	1,953,125	11·180	5·000
126	395·84	12468·98	15,876	2,000,376	11·224	5·013
127	398·98	12667·69	16,129	2,048,383	11·269	5·026
128	402·12	12867·96	16,384	2,097,152	11·313	5·039
129	405·26	13069·81	16,641	2,146,689	11·357	5·052
130	408·41	13273·23	16,900	2,197,000	11·401	5·065
131	411·55	13478·22	17,161	2,248,091	11·445	5·078
132	414·69	13684·78	17,424	2,299,968	11·489	5·091
133	417·83	13892·91	17,689	2,352,637	11·532	5·104
134	420·97	14102·61	17,956	2,406.104	11·575	5·117
135	424·11	14313·88	18,225	2,460,375	11·618	5·129
136	427·26	14526·72	18,496	2,515,456	11·661	5·142
137	430·40	14741·14	18,769	2,571.353	11·704	5·155
138	433·54	14957·12	19,044	2,620,872	11·747	5·167
139	436·68	15174·68	19,321	2,685,619	11·789	5·180
140	439·82	15393·80	19,600	2,744.000	11·832	5·192
141	442·96	15614·50	19.881	2,803,221	11·874	5·204
142	446·11	15836·77	20,164	2,863,288	11·916	5·217
143	449·25	16060·61	20,449	2,924,207	11·958	5·229
144	452·39	16286·02	20.736	2,985.984	12·000	5·241
145	455·53	16513·00	21.025	3,048,625	12·041	5·253
146	458·67	16741·55	21.316	3,112,136	12·083	5·265
147	461·81	16971·67	21,609	3,176,523	12·124	5·277
148	464·96	17203·36	21,904	3,241,792	12·165	5·289
149	468·10	17436·62	22,201	3,307,949	12·206	5·301
150	471·24	17671·46	22,500	3,375,000	12·247	5·313
151	474·38	17907·86	22,801	3,442,951	12·288	5·325
152	477·52	18145·84	23,104	3,511,808	12·328	5·336
153	480·66	18385·39	23,409	3,581,577	12·369	5·348
154	483·80	18626·50	23,716	3,652.264	12·409	5·360
155	486·95	18869·19	24,025	3,723.875	12·449	5·371
156	490·09	19113·45	24,336	3,796.416	12·489	5·383
157	493·23	19359·28	24,649	3,869,893	12·529	5·394
158	496·37	19606·68	24,964	3,944,312	12·569	5·406
159	499·51	19855·65	25,281	4,019.679	12·609	5·417
160	502·65	20106·19	25,600	4,096,000	12·649	5·428
161	505·80	20358·34	25,921	4,173,281	12·688	5·440
162	508·94	20611·99	26.244	4.251.528	12·727	5·451
163	512·08	20867·24	26,569	4.330,747	12·767	5·462
164	515·22	21124·07	26,896	4,410,944	12·806	5·473
165	518·36	21382·46	27,225	4,492,125	12·845	5·484

No. or Diam.	Circumference.	Circular Area.	Square.	Cube.	Square Root.	Cube Root.
166	521·50	21642·43	27,556	4,574,296	12·844	5·495
167	524·65	21903·97	27,889	4,657,463	12·922	5·506
168	527·79	22167·08	28,224	4,741,632	12·961	5·517
169	530·93	22431·76	28,561	4,826,809	13·000	5·528
170	534·07	22698·01	28,900	4,913,000	13·038	5·539
171	537·21	22965·83	29,241	5,000,211	13·076	5·550
172	540·35	23235·22	29,584	5,088,448	13·114	5·561
173	543·50	23506·18	29,929	5,177,717	13·152	5·572
174	546·64	23778·71	30,276	5,268,024	13·190	5·582
175	549·78	24052·82	30,625	5,359·375	13·228	5·593
176	552·92	24328·49	30,976	5,451,776	13·266	5·604
177	556·06	24605·79	31,329	5,545,233	13·304	5·614
178	559·20	24884·56	31,684	5,639,752	13·341	5·625
179	562·34	25164·94	32,041	5,735,339	13·379	5·635
180	565·49	25446·90	32,400	5,832,000	13·416	5·646
181	568·63	25730·43	32,761	5,929,741	13·453	5·656
182	571·77	26015·53	33,124	6,028,568	13·490	5·667
183	574·91	26302·20	33,489	6,128,487	13·527	5·677
184	578·05	26590·44	33,856	6,229,504	13·564	5·687
185	581·19	26880·25	34,225	6,331,625	13·601	5·698
186	584·34	27171·63	34,596	6,434,856	13·638	5·708
187	587·48	27464·59	34,969	6,539,203	13·674	5·718
188	590·62	27759·11	35,344	6,644,672	13·711	5·728
189	593·76	28055·21	35,721	6,751,269	13·747	5·738
190	596·90	28352·87	36,100	6,859,000	13·784	5·748
191	600·04	28652·11	36,481	6,967,871	13·820	5·758
192	603·19	28952·92	36,864	7,077,888	13·856	5·768
193	606·33	29255·30	37,249	7,189,057	13·892	5·778
194	609·47	29559·26	37,636	7,301,384	13·928	5·788
195	612·61	29864·77	38,025	7,414,875	13·964	5·798
196	615·75	30171·86	38,416	7,529,536	14·000	5·808
197	618·89	30480·52	38,809	7,645,373	14·035	5·818
198	622·03	30790·75	39,204	7,762,392	14·071	5·828
199	625·18	31102·55	39,601	7,880,599	14·106	5·838
200	628·32	31415·93	40,000	8,000,000	14·142	5·848
201	631·46	31730·87	40,401	8,120,601	14·177	5·857
202	634·60	32047·39	40,804	8,242,408	14·212	5·867
203	637·74	32365·47	41,209	8,365,427	14·247	5·877
204	640·88	32685·13	41,616	8,489,664	14·282	5·886
205	644·03	33006·36	42,025	8,615,125	14·317	5·896
206	647·17	33329·16	42,436	8,741,816	14·352	5·905
207	650·31	33653·53	42,849	8,869,743	14·387	5·915

No. or Diam.	Circumference.	Circular Area.	Square.	Cube.	Square Root.	Cube Root.
208	653·45	33979·47	43,264	8,998,912	14·422	5·924
209	656·59	34306·98	43,681	9,123,329	14·456	5·934
210	659·73	34636·06	44,100	9,261,000	14·491	5·943
211	662·88	34966·71	44,521	9,393,931	14·525	5·953
212	666·02	35298·94	44,944	9,528,128	14·560	5·962
213	669·16	35632·73	45,369	9,663,597	14·594	5·972
214	672·30	35968·09	45,796	9,800,344	14·628	5·981
215	675·44	36305·03	46,225	9,938,375	14·662	5·990
216	678·58	36643·61	46,656	10,077,696	14·696	6·000
217	681·73	36983·61	47,089	10,218,313	14·730	6·009
218	684·87	37325·26	47,524	10,360,232	14·764	6·018
219	688·01	37668·48	47,961	10,503,459	14·798	6·027
220	691·15	38013·27	48,400	10,648,000	14·832	6·036
221	694·29	38359·63	48,841	10,793,861	14·866	6·045
222	697·43	38707·56	49,284	10,941,048	14·899	6·055
223	700·57	39057·07	49,729	11,089,567	14·933	6·064
224	703·72	39408·14	50,176	11,239,424	14·966	6·073
225	706·86	39760·78	50,625	11,390,625	15·000	6·082
226	710·00	40115·00	51,076	11,543,176	15·033	6·091
227	713·14	40470·78	51,529	11,697,083	15·066	6·100
228	716·28	40828·14	51,984	11,852,352	15·099	6·109
229	719·42	41187·07	52,441	12,008,989	15·132	6·118
230	722·57	41547·56	52,900	12,167,000	15·165	6·126
231	725·71	41909·63	53,361	12,326,391	15·198	6·135
232	728·85	42273·27	53,824	12,487,168	15·231	6·144
233	731·99	42638·48	54,289	12,649,337	15·264	6·153
234	735·13	43005·26	54,756	12,812,904	15·297	6·162
235	738·27	43373·61	55,225	12,977,875	15·329	6·171
236	741·42	43743·54	55,696	13,144,256	15·362	6·179
237	744·56	44115·03	56,169	13,312,053	15·394	6·188
238	747·70	44488·09	56,644	13,481,272	15·427	6·197
239	750·84	44862·73	57,121	13,651,919	15·459	6·205
240	753·98	45238·93	57,600	13,824,000	15·491	6·214
241	757·12	45616·71	58,081	13,997,521	15·524	6·223
242	760·26	45996·06	58,564	14,172,488	15·556	6·231
243	763·41	46376·98	59,049	14,348,907	15·588	6·240
244	766·55	46759·47	59,536	14,526,784	15·620	6·248
245	769·69	47143·52	60,025	14,706,125	15·652	6·257
246	772·83	47529·16	60,516	14,886,936	15·684	6·265
247	775·97	47916·36	61,009	15,069,223	15·716	6·274
248	779·11	48305·13	61,504	15,252,992	15·748	6·282
249	782·26	48695·47	62,001	15,438,249	15·779	6·291

No. or Diam.	Circumference.	Circular Area.	Square.	Cube.	Square Root.	Cube Root.
250	785·40	49087·39	62,500	15,625,000	15·811	6·299
251	788·54	49480·87	63,001	15,813,251	15·842	6·307
252	791·68	49875·92	63,504	16,003,008	15·874	6·316
253	794·82	50272·55	64,009	16,194,277	15·905	6·324
254	797·96	50670·75	64,516	16,387,064	15·937	6·333
255	801·11	51070·52	65,025	16,581,375	15·968	6·341
256	804·25	51471·86	65,536	16,777,216	16·000	6·349
257	807·39	51874·76	66,049	16,974,593	16·031	6·357
258	810·53	52279·24	66,564	17,173,512	16·062	6·366
259	813·67	52685·29	67,081	17,373,979	16·093	6·374
260	816·81	53092·96	67,600	17,576,000	16·124	6·382
261	819·96	53502·11	68,121	17,779,581	16·155	6·390
262	823·10	53912·87	68,644	17,984,728	16·186	6·398
263	826·24	54325·21	69,169	18,191,447	16·217	6·406
264	829·38	54739·11	69,696	18,399,744	16·248	6·415
265	832·52	55154·59	70,225	18,609,625	16·278	6·423
266	835·66	55571·63	70,756	18,821,096	16·309	6·431
267	838·80	55990·25	71,289	19,034,163	16·340	6·439
268	841·95	56410·44	71,824	19,248,832	16·370	6·447
269	845·09	56832·20	72,361	19,465,109	16·401	6·455
270	848·23	57255·53	72,900	19,683,000	16·431	6·463
271	851·37	57680·43	73,441	19,902,511	16·462	6·471
272	854·51	58106·90	73,984	20,123,648	16·492	6·479
273	857·65	58534·94	74,529	20,346,417	16·522	6·487
274	860·80	58964·55	75,076	20,570,824	16·552	6·495
275	863·94	59395·74	75,625	20,796,875	16·583	6·502
276	867·08	59828·49	76,176	21,024,576	16·613	6·510
277	870·22	60262·82	76,729	21,253,933	16·643	6·518
278	873·36	60698·72	77,284	21,484,952	16·673	6·526
279	876·50	61136·18	77,841	21,717,639	16·703	6·534
280	879·65	61575·22	78,400	21,952,000	16·733	6·542
281	882·79	62015·82	78,961	22,188,041	16·763	6·549
282	885·93	62458·00	79,524	22,425,768	16·792	6·557
283	889·07	62901·75	80,089	22,665,187	16·822	6·565
284	892·21	63347·07	80,656	22,906,304	16·852	6·573
285	895·35	63793·97	81,225	23,149,125	16·881	6·580
286	898·49	64242·43	81,796	23,393,656	16·911	6·588
287	901·64	64692·46	82,369	23,639,903	16·941	6·596
288	904·78	65144·07	82,944	23,887,872	16·970	6·603
289	907·92	65597·24	83,521	24,137,569	17·000	6·611
290	911·06	66051·99	84,100	24,389,000	17·029	6·619
291	914·20	66508·30	84,681	24,642,171	17·059	6·627

No. or Diam.	Circumference.	Circular Area.	Square.	Cube.	Square Root.	Cube Root.
292	917·34	66966·19	85,264	24,897,088	17·088	6·634
293	920·49	67425·65	85,849	25,153,757	17·117	6·642
294	923·63	67886·68	86,436	25,412,184	17·146	6·649
295	926·77	68349·28	87,025	25,672,375	17·176	6·657
296	929·91	68813·45	87,616	25,934,336	17·205	6·664
297	933·05	69279·19	88,209	26,198,073	17·234	6·672
298	936·19	69746·50	88,804	26,463,592	17·263	6·679
299	939·34	70215.38	89,401	26,730,899	17·292	6·687
300	942·48	70685·83	90,000	27,000,000	17·320	6·694
301	945·62	71157·86	90,601	27,270,901	17·349	6·702
302	948·76	71631·45	91,204	27,543,608	17·378	6·709
303	951·90	72106·62	91,809	27,818,127	17·407	6·717
304	955·04	72583·36	92,416	28,094,464	17·436	6·724
305	958·19	73061·66	93,025	28,372,625	17·464	6·731
306	961·33	73541·54	93,636	28,652,616	17·493	6·739
307	964·47	74022·99	94,249	28,934,443	17·521	6·746
308	967·61	74506·01	94,864	29,218,112	17·549	6·753
309	970·75	74990·60	95,481	29,503,629	17·578	6·761
310	973·89	75476·76	96,100	29,791,000	17·607	6·768
311	977·03	75964·50	96,721	30,080,231	17·635	6·775
312	980·18	76453·80	97,344	30,371,328	17·663	6·782
313	983·32	76944·67	97,969	30,664.297	17·692	6·789
314	986·46	77437·12	98,596	30,959,144	17·720	6·797
315	989·60	77931·13	99,225	31,255,875	17·748	6·804
316	992·74	78426·72	99,856	31,554,496	17·776	6·811
317	995·88	78923·88	100,489	31,855,013	17·804	6·818
318	999·03	79422·60	101,124	32,157,432	17·832	6·826
319	1002·17	79922·90	101,761	32,461,759	17·860	6·833
320	1005·31	80424·77	102,400	32,768,000	17·888	6·839
321	1008·45	80928·21	103,041	33,076,161	17·916	6·847
322	1011·59	81433·22	103,684	33,386,248	17·944	6·854
323	1014·73	81939·80	104,329	33,698,267	17·972	6·861
324	1017·88	82447·96	104,976	34,012,224	18·000	6·868
325	1021·02	82957·68	105,625	34,328,125	18·028	6·875
326	1024·16	83468·98	106,276	34,645,976	18·055	6·882
327	1027·30	83981·84	106,929	34,965,783	18·083	6·889
328	1030·44	84496·28	107,584	35,287,552	18·111	6·896
329	1033·58	85012·28	108,241	35,611,289	18·138	6·903
330	1036·73	85529·86	108,900	35,937,000	18·166	6·910
331	1039·87	86049.01	109,561	36,264,691	18·193	6·917
332	1043·01	86569·73	110,224	36,594,368	18·221	6·924
333	1046·15	87092·02	110,889	36,926,037	18·248	6·931

No. or Diam.	Circumference.	Circular Area.	Square.	Cube.	Square Root.	Cube Root.
334	1049·29	87615·88	111,556	37,259,704	18·276	6·938
335	1052·43	88141·31	112,225	37,595,375	18·303	6·945
336	1055·57	88668·31	112,896	37,933,056	18·330	6·952
337	1058·72	89196·88	113,569	38,272,753	18·357	6·959
338	1061·86	89727·03	114,244	38,614,472	18·385	6·966
339	1065·00	90258·74	114,921	38,958,219	18·412	6·973
340	1068·14	90792·03	115,600	39,304,000	18·439	6·979
341	1071·28	91326·88	116,281	39,651,821	18·466	6·986
342	1074·42	91863·31	116,964	40,001,688	18·493	6·993
343	1077·57	92401·31	117,649	40,353,607	18·520	7·000
344	1080·71	92940·88	118,336	40,707,584	18·547	7·007
345	1083·85	93482·02	119,025	41,063,625	18·574	7·014
346	1086·99	94024·73	119,716	41,421,736	18·601	7·020
347	1090·13	94569·01	120,409	41,781,923	18·628	7·027
348	1093·27	95114·86	121,104	42,144,192	18·655	7·034
349	1096·42	95662·28	121,801	42,508,549	18·681	7·040
350	1099·56	96211·28	122,500	42,875,000	18·708	7·047
351	1102·70	96761·84	123,201	43,243,551	18·735	7·054
352	1105·84	97314·76	123,904	43,614,208	18·762	7·061
353	1108·98	97867·68	124,609	43,986,977	16·788	7·067
354	1112·12	98422·96	125,316	44,361,864	18·815	7·074
355	1115·26	98979·80	126,025	44,738,875	18·842	7·081
356	1118·41	99538·22	126,736	45,118,016	18·868	7·087
357	1121·55	100098·21	127,449	45,499,293	18·894	7·094
358	1124·69	100659·27	128,164	45,882,712	18·921	7·101
359	1127·83	101222·90	128,881	46,268,279	18·947	7·107
360	1130·97	101787·60	129,600	46,656,000	18·974	7.114
361	1134·11	102353·87	130,321	47,045,881	19·000	7·120
362	1137·26	102921·72	131,044	47,437,928	19·026	7·127
363	1140·40	103491·13	131,769	47,832,147	19·052	7·133
364	1143·54	104062·12	132,496	48,228,544	19·079	7·140
365	1146·68	104634·67	133,225	48,627,125	19·105	7·146
366	1149·82	105208·80	133,956	49,027,896	19·131	7·153
367	1152·96	105784·49	134,689	49,430,863	19·157	7·159
368	1156·11	106361·76	135,424	49,836,032	19·183	7·166
369	1159·25	106940·60	136,161	50,243,409	19·209	7·172
370	1162·39	107521·01	136,900	50,653,000	19·235	7·179
371	1165·53	108102·99	137,641	51,064,811	19·261	7·185
372	1168·67	108686·54	138,384	51,478,848	19·287	7·192
373	1171·81	109271·66	139,129	51,895,117	19·313	7·198
374	1174·96	109858·35	139,876	52,313,624	19·339	7·205
375	1178·10	110446·62	140,625	52,734,375	19·365	7·211

No. or Diam.	Circumference.	Circular Area.	Square.	Cube.	Square Root.	Cube Root
376	1181·24	111036·45	141,376	53,157,376	19·391	7·218
377	1184·38	111627·86	142,129	53,582,633	19·416	7·224
378	1187·52	112220·83	142,884	54,010,152	19·442	7·230
379	1190·66	112815·38	143,641	54,439,939	19·468	7·237
380	1193·80	113411·49	144,400	54,872,000	19·493	7·243
381	1196·95	114009·18	145,161	55,306,341	19·519	7·249
382	1200·09	114608·44	145,924	55,742,968	19·545	7·256
383	1203·23	115209·27	146,689	56,181,887	19·570	7·262
384	1206·37	115811·67	147,456	56,623,104	19·596	7·268
385	1209·51	116415·64	148,225	57,066,625	19·621	7·275
386	1212·65	117021·18	148,996	57,512,456	19·647	7·281
387	1215·80	117628·30	149,769	57,960,603	19·672	7·287
388	1218·94	118236·98	150,544	58,411,072	19·698	7·294
389	1222·08	118847·24	151,321	58,863,869	19·723	7·299
390	1225·22	119459·06	152,100	59,319,000	19·748	7·306
391	1228·36	120072·46	152,881	59,776,471	19·774	7·312
392	1231·50	120687·42	153,664	60,236,288	19·799	7·319
393	1234·65	121303·96	154,449	60,698,457	19·824	7·325
394	1237·79	121922·07	155,236	61,162,984	19·849	7·331
395	1240·93	122541·75	156,025	61,629,875	19·875	7·337
396	1244·07	123163·00	156,816	62,099,136	19·899	7·343
397	1247·21	123785·82	157,609	62,570,773	19·925	7·349
398	1250·35	124410·21	158,404	63,044,792	19·949	7·356
399	1253·49	125036·17	159,201	63,521,199	19·975	7·362
400	1256·64	125663·71	160,000	64,000,000	20·000	7·368
401	1259·78	126292·81	160,801	64,481,201	20·025	7·374
402	1262·92	126923·48	161,604	64,964,808	20·049	7·380
403	1266·06	127553·73	162,409	65,450,827	20·075	7·386
404	1269·20	128189·55	163,216	65,939,264	20·099	7·392
405	1272·34	128824·93	164,025	66,430,125	20·125	7·399
406	1275·49	129461·89	164,836	66,923,416	20·149	7·405
407	1278·63	130100·42	165,649	67,419,143	20·174	7·411
408	1281·77	130740·52	166,464	67,911,312	20·199	7·417
409	1284·91	131382·19	167,281	68,417,929	20·224	7·422
410	1288·05	132025·43	168,100	68,921,000	20·248	7·429
411	1291·19	132670·24	168,921	69,426,531	20·273	7·434
412	1294·34	133316·63	169,744	69,934,528	20·298	7·441
413	1297·48	133964·58	170,569	70,444,997	20·322	7·447
414	1300·62	134614·10	171,396	70,957,944	20·347	7·453
415	1303·76	135265·20	172,225	71,473,375	20·371	7·459
416	1306·90	135917·86	173,056	71,991,296	20·396	7·465
417	1310·04	136572·10	173,889	72,511,713	20·421	7·471

o. r am.	Circumference.	Circular Area.	Square.	Cube.	Square Root.	Cube Root.
18	1313·19	137227·91	174,724	73,034,632	20·445	7·477
19	1316·33	137885·29	175,561	73,560,059	20·469	7·483
20	1319·47	138544·24	176,400	74,088,000	20·494	7·489
21	1322·61	139204·70	177,241	74,618,461	20·518	7·495
422	1325·75	139866·85	178,084	75,151,448	20·543	7·501
423	1328·89	140530·51	178,929	75,686,967	20·567	7·507
424	1332·03	141195·74	179,776	76,225,024	20·591	7·513
425	1335·18	141862·54	180,625	76,765,625	20·615	7·518
426	1338·32	142530·92	181,476	77,308,776	20·639	7·524
427	1341·46	143200·86	182,329	77,854,483	20·664	7·530
428	1344·60	143872·38	183,184	78,402,752	20·688	7·536
429	1347·74	144545·46	184,041	78,953,589	20·712	7·542
430	1550·88	145220·12	184,900	79,507,000	20·736	7·548
431	1354·03	145896·35	185,761	80,062,991	20·760	7·554
432	1357·17	146574·15	186,624	80,621,568	20·785	7·559
433	1360·31	147253·52	187,489	81.182,737	20·809	7·565
434	1363·45	147934·46	188,356	81,746,504	20·833	7·571
435	1366·59	148616·97	189,225	82,312,875	20·857	7·577
436	1369·73	149301·05	190,096	82,881,856	20·881	7·583
437	1372·88	149986·70	190,969	83,453,453	20·904	7·588
438	1376·02	150673·93	191,844	84,027,672	20·928	7·594
439	1379·16	151362·72	192,721	84,604,519	20·952	7·600
440	1382·30	152053·08	193,600	85,184,000	20·976	7·606
441	1385·44	152745·02	194,481	85,766,121	21·000	7·612
442	1388·58	153438·53	195,364	86,350,388	21·024	7·617
443	1391·73	154133·60	196,249	86,938,307	21·047	7·623
444	1394·87	154830·25	197,136	87,528,384	21·071	7·629
445	1398·01	155528·47	198,025	88,121,125	21·095	7·635
446	1401·15	156228·26	198,916	88,716,536	21·119	7·640
447	1404·29	156929·62	199,809	89,314,623	21·142	7·646
448	1407·43	157632·55	200,704	89,915,392	21·166	7·652
449	1410·57	158337·06	201,601	90,518,849	21·189	7·657
450	1413·72	159043·13	202,500	91,125,000	21·213	7·663
451	1416·86	159750·77	203,401	91,733,851	21·237	7·669
452	1420·00	160459·99	204,304	92,345,408	21·260	7·674
453	1423·14	161170·77	205,209	92,959,677	21·284	7·680
454	1426·28	161883·13	206,106	93,576,664	21·307	7·686
455	1429·42	162597·06	207,025	94,196,375	21·331	7·691
456	1432·57	163312·55	207,936	94,818,816	21·354	7·697
457	1435·71	164029·62	208,849	95,443,993	21·377	7·703
458	1438·85	164748·26	209,764	96,071,912	21·401	7·708
459	1441·99	165468·47	210.681	96.702,579	21·424	7·714

No. or Diam.	Circumference.	Circular Area.	Square.	Cube.	Square Root.	Cube Root.
460	1445·13	166190·25	211,600	97,336,000	21·447	7·719
461	1448·27	166913·60	212,521	97,972,181	21·471	7·725
462	1451·42	167638·53	213,444	98,611,128	21·494	7·731
463	1454·56	168365·02	214,369	99,252,847	21·517	7·736
464	1457·70	169093·08	215,296	99,897,345	21·541	7·742
465	1460·84	169822·72	216,225	100,544,625	21·564	7·747
466	1463·98	170553·92	217,156	101,194,696	21·587	7·753
467	1467·12	171286·70	218,089	101,847,563	21·610	7·758
468	1470·26	172021·05	219,024	102,503,232	21·633	7·764
469	1473·41	172756·97	219,961	103,161,709	21·656	7·769
470	1476·55	173494·45	220,900	103,823,000	21·679	7·775
471	1479·69	174233·51	221,841	104,487,111	21·702	7·780
472	1482·83	174974·14	222,784	105,154,048	21·725	7·786
473	1485·97	175716·35	223,729	105,823,817	21·749	7·791
474	1489·11	176460·12	224,676	106,496,424	21·771	7·797
475	1492·26	177205·46	225,625	107,171,875	21·794	7·802
476	1495·40	177952·37	226,576	107,850,176	21·817	7·808
477	1498·54	178700·86	227,529	108,531,333	21·840	7·813
478	1501·68	179450·91	228,484	109,215,352	21·863	7·819
479	1504·82	180202·54	229,441	109,902,239	21·886	7·824
480	1507·96	180955·74	230,400	110,592,000	21·909	7·830
481	1511·11	181710·50	231,361	111,284,641	21·932	7·835
482	1514·25	182466·84	232,324	111,980,168	21·954	7·840
483	1517·39	183224·75	233,289	112,678,587	21·977	7·846
484	1520·53	183984·23	234,256	113,379,904	22·000	7·851
485	1523·67	184745·28	235,225	114,084,125	22·023	7·857
486	1526·81	185507·90	236,196	114,791,256	22·045	7·862
487	1529·96	186272·10	237,169	115,501,303	22·069	7·868
488	1533·10	187037·86	238,144	116,214,272	22·091	7·873
489	1536·24	187805·19	239,121	116,936,169	22·113	7·878
490	1539·38	188574·10	240,100	117,649,000	22·136	7·884
491	1542·52	189344·57	241,081	118,370,771	22·158	7·889
492	1545·66	190116·62	242,064	119,095,488	22·181	7·894
493	1548·80	190890·24	243,049	119,823,157	22·204	7·899
494	1551·95	191665·43	244,036	120,553,784	22·226	7·905
495	1555·09	192442·19	245,025	121,287,375	22·248	7·910
496	1558·23	193220·51	246,016	122,023,936	22·271	7·915
497	1561·37	194000·42	247,009	122,763,473	22·293	7·921
498	1564·51	194781·89	248,004	123,505,992	22·316	7·926
499	1567·65	195564·93	249,001	124,251,499	22·338	7·932
500	1570·80	196349·54	250,000	125,000,000	22·361	7·937
501	1573·94	197135·72	251,001	125,751,501	22·383	7·942

No. or iam.	Circumference.	Circular Area.	Square.	Cube.	Square Root.	Cube Root.
502	1577·08	197923·48	252,004	126,506,008	22·405	7·947
503	1580·22	198712·80	253,009	127,263,527	22·428	7·953
504	1583·36	199503·70	254,016	128,024,864	22·449	7·958
505	1586·50	200296·17	255,025	128,787,625	22·472	7·963
506	1589·65	201090·20	256,036	129,554,216	22·494	7·969
507	1592·79	201885·81	257,049	130,323,843	22·517	7·974
508	1595·93	202682·99	258,064	131,096,512	22·539	7·979
509	1599·07	203481·74	259,081	131,872,229	22·561	7·984
510	1602·21	204282·06	260.100	132,651,000	22·583	7·989
511	1605·35	205083·95	261,121	133,432,831	22·605	7·995
512	1608·49	205887·42	262,144	134,217,728	22·627	8·000
513	1611·64	206692·45	263,169	135,005,697	22·649	8·005
514	1614·78	207499·05	264,196	135,796,744	22·671	8·010
515	1617·92	208307·23	265,225	136,590,875	22·694	8·016
516	1621·06	209116·97	266,256	137,388,096	22·716	8·021
517	1624·20	209928·29	267,289	138,188,413	22·738	8·026
518	1627·34	210741·18	268,324	138,991,832	22·759	8·031
519	1630·49	211555·63	269,361	139,798.359	22·782	8·036
520	1633·63	212371·66	270,400	140,608.000	22·803	8·041
521	1636·77	213189·26	271,441	141,420.761	22·825	8·047
522	1639·91	214008·43	272,484	142,236,648	22·847	8·052
523	1643·05	214829·17	273,529	143,055,667	22·869	8·057
524	1646·19	215651·49	274,576	143,877,824	22·891	8·062
525	1649·34	216475·37	275,625	144,703,125	22·913	8·067
526	1652·48	217300·82	276,676	145,531,576	22·935	8·072
527	1655·62	218127·85	277,729	146,363,183	22·956	8·077
528	1658·76	218956·44	278,784	147,197,952	22·978	8·082
529	1661·90	219786·61	279,841	148,035,889	23·000	8·087
530	1665·04	220618·32	280,900	148,877,000	23·022	8·093
531	1668·19	221451·65	281,961	149,721.291	23·043	8·098
532	1671·33	222286·53	283,024	150,568,768	23·065	8·103
533	1674·47	223122·98	284,089	151,419,437	23·087	8·108
534	1677·61	223961·00	285,156	152,273.304	23·108	8·113
535	1680·75	224800·59	286,225	153,130.375	23·130	8·118
536	1683·89	225641·75	287,296	153,990.656	23·152	8·123
537	1687·04	226484·48	288,369	154,854.153	23·173	8·128
538	1690·18	227328·77	289,444	155,720,872	23·195	8·133
539	1693·32	228174·66	290,521	156,590,819	23·216	8·138
540	1696·46	229022·10	291,600	157,464.000	23·238	8·143
541	1699·60	229871·12	292,681	158,340,421	23·259	8·148
542	1702·74	230721·71	293,764	159,220,088	23·281	8·153
543	1705·88	231573·86	294,849	160,103,007	23·302	8·158

No. or Diam.	Circumference	Circular Area.	Square.	Cube.	Square Root.	Cube Root.
544	1709·03	232427·59	295,936	160,989,184	23·324	8·163
545	1712·17	233282·89	297,025	161,878,625	23·345	8·168
546	1715·31	234139·76	298,116	162,771,336	23·367	8·173
547	1718·45	234998·20	299,209	163,667,323	23·388	8·178
548	1721·59	235858·21	300,304	164,566,592	23·409	8·183
549	1724·73	236719·79	301,401	165,469,149	23·431	8·188
550	1727·88	237582·94	302,500	166,375,000	23·452	8·193
551	1731·02	238447·67	303,601	167,284,151	23·473	8·198
552	1734·16	239313·96	304,704	168,196,608	23·495	8·203
553	1737·30	240181·83	305,809	169,112,377	23·516	8·208
554	1740·44	241051·26	306,916	170,031,464	23·537	8·213
555	1743·58	241922·27	308,025	170,953,875	23·558	8·218
556	1746·73	242794·85	309,136	171,879,616	23·579	8·223
557	1749·87	243668·99	310,249	172,808,693	23·601	8·228
558	1753·00	244544·61	311,364	173,741,112	23·622	8·233
559	1756·15	245422·00	312,481	174,676,879	23·643	8·238
560	1759·29	246300·86	313,600	175,616,000	23·664	8·242
561	1762·43	247181·30	314,721	176,558,481	23·685	8·247
562	1765·57	248062·30	315,844	177,504,328	23·706	8·252
563	1768·72	248946·87	316,969	178,453,547	23·728	8·257
564	1771·86	249832·01	318,096	179,406,144	23·749	8·262
565	1775·00	250718·73	319,225	180,362,125	23·769	8·267
566	1778·14	251607·01	320,356	181,321,496	23·791	8·272
567	1781·28	252496·87	321,489	182,284,263	23·812	8·277
568	1784·42	253388·30	322,624	183,250,432	23·833	8·282
569	1787·57	254281·30	323,761	184,220,009	23·854	8·286
570	1790·71	255175·86	324,900	185,193,000	23·875	8·291
571	1793·85	256072·00	326,041	186,169,411	23·896	8·296
572	1796·99	256969·71	327,184	187,149,248	23·916	8·301
573	1800·13	257868·99	328,329	188,132,517	23·937	8·306
574	1803·27	258769·85	329,476	189,119,224	23·958	8·311
575	1806·42	259672·27	330,625	190,109,375	23·979	8·315
576	1809·56	260576·26	331,776	191,102,976	24·000	8·320
577	1812·70	261481·83	332,929	192,100,033	24·021	8·325
578	1815·84	262388·96	334,084	193,100,552	24·042	8·330
579	1818·98	263297·67	335,241	194,104,539	24·062	8·335
580	1822·12	264207·94	336,400	195,112,000	24·083	8·339
581	1825·26	265119·79	337,561	196,122,941	24·104	8·344
582	1828·41	266033·21	338,724	197,137,368	24·125	8·349
583	1831·55	266948·20	339,889	198,155,287	24·145	8·354
584	1834·69	267864·76	341,056	199,176,704	24·166	8·359
585	1837·83	268782·80	342,225	200,201,625	21·187	8·363

No. or Diam.	Circumference.	Circular Area.	Square.	Cube.	Square Root.	Cube Root.
586	1840·97	269702·59	343,396	201,230,056	24·207	8·368
587	1844·11	270623·86	344,569	202,262,003	24·228	8·373
588	1847·26	271546·70	345,744	203,297,472	24·249	8·378
589	1850·40	272471·12	346,921	204,336,469	24·269	8·382
590	1853·54	273397·10	348,100	205,379,000	24·289	8·387
591	1856·68	274324·66	349,281	206,425,071	24·310	8·392
592	1859·82	275253·78	350,464	207,474,688	24·331	8·397
593	1862·96	276184·48	351,649	208,527,857	24·351	8·401
594	1866·11	277116·75	352,836	209,584,584	24·372	8·406
595	1869·25	278050·59	354,025	210,644,875	24·393	8·411
596	1872·39	278985·99	355,216	211,708,736	24·413	8·415
597	1875·53	279922·97	356,409	212,776,173	24·433	8·420
598	1878·67	280861·53	357,604	213,847,192	24·454	8·425
599	1881·81	281801·65	358,801	214,921,799	24·474	8·429
600	1884·96	282743·34	360,000	216,000,000	24·495	8·434
601	1888·10	283686·60	361,201	217,081,801	24·515	8·439
602	1891·24	284631·44	362,404	218,167,208	24·536	8·444
603	1894·38	285577·84	363,609	219,256,227	24·556	8·448
604	1897·52	286525·82	364,816	220,348,864	24·576	8·453
605	1900·66	287475·36	366,025	221,445,125	24·597	8·458
606	1903·80	288426·48	367,236	222,545,016	24·617	8·462
607	1906·95	289379·17	368,449	223,648,543	24·637	8·467
608	1910·09	290333·43	369,664	224,755,712	24·658	8·472
609	1913·23	291289·26	370,881	225,866,529	24·678	8·476
610	1916·37	292246·66	372,100	226,981,000	24·698	8·481
611	1919·51	293205·63	373,321	228,099,131	24·718	8·485
612	1922·65	294166·17	374,544	229,220,928	24·739	8·490
613	1925·80	295128·28	375,769	230,346,397	24·758	8·495
614	1928·94	296091·97	376,996	231,475,544	24·779	8·499
615	1932·08	297057·22	378,225	232,608,375	24·799	8·504
616	1935·22	298024·05	379,456	233,744,896	24·819	8·509
617	1938·36	298992·44	380,689	234,885,113	24·839	8·513
618	1941·50	299962·41	381,924	236,029,032	24·859	8·518
619	1944·65	300933·95	383,161	237,176,659	24·879	8·522
620	1947·79	301907·05	384,400	238,628,000	24·899	8·527
621	1950·93	302881·73	385,641	239,483,061	24·919	8·532
622	1954·07	303857·98	386,884	240,641,848	24·939	8·536
623	1957·21	304835·80	388,129	241,804,367	24·959	8·541
624	1960·35	305815·20	389,376	242,970,624	24·980	8·545
625	1963·50	306796·16	390,625	244,140,625	25·000	8·549
626	1966·64	307778·69	391,876	245,314,376	25·019	8·554
627	1969·78	308762·79	393,129	246,491,883	25·040	8·559

No. or Diam.	Circumference.	Circular Area.	Square.	Cube.	Square Root.	Cube Root.
628	1972·92	309748·47	394,384	247,673,152	25·059	8·563
629	1976·06	310735·71	395,641	248,858,189	25·079	8·568
630	1979·20	311724·53	396,900	250,047,000	25·099	8·573
631	1982·34	312714·92	398,161	251,239,591	25·119	8·577
632	1985·49	313706·88	399,424	252,435,968	25·139	8·582
633	1988·63	314700·40	400,689	253,636,137	25·159	8·586
634	1991·77	315695·50	401,956	254,840,104	25·179	8·591
635	1994·91	316692·17	403,225	256,047,875	25·199	8·595
636	1998·05	317690·42	404,496	257,259,456	25·219	8·599
637	2001·19	318690·23	405,769	258,474,853	25·239	8·604
638	2004·34	319691·61	407,044	259,694,072	25·259	8·609
639	2007·48	320694·56	408,321	260,917,119	25·278	8·613
640	2010·62	321699·09	409,600	262,144,000	25·298	8·618
641	2013·76	322705·18	410,881	263,374,721	25·318	8·622
642	2016·90	323712·85	412,164	264,609,288	25·338	8·627
643	2020·04	324722·09	413,449	265,847,707	25·357	8·631
644	2023·19	325732·89	414,736	267,089,984	25·377	8·636
645	2026·33	326745·27	416,025	268,836,125	25·397	8·640
646	2029·47	327759·22	417,316	269,586,136	25·416	8·644
647	2032·61	328774·74	418,609	270,840,023	25·436	8·649
648	2035·75	329791·83	419,904	272,097,792	25·456	8·653
649	2038·89	330810·49	421,201	273,359,449	25·475	8·658
650	2042·04	331830·72	422,500	274,625,000	25·495	8·662
651	2045·18	332852·53	423,801	275,894,451	25·515	8·667
652	2048·32	333875·90	425,104	277,167,808	25·534	8·671
653	2051·46	334900·85	426,409	278,445,077	25·554	8·676
654	2054·60	335927·36	427,716	279,726,264	25·573	8·680
655	2057·74	336955·45	429,025	281,011,375	25·593	8·684
656	2060·88	337985·10	430,336	282,800,416	25·612	8·689
657	2064·03	339016·33	431,649	283,593,393	25·632	8·693
658	2067·17	340049·13	432,964	284,890,312	25·651	8·698
659	2070·31	341083·50	434,281	286,191,179	25·671	8·702
660	2073·45	342119·44	435,600	287,496,000	25·690	8·706
661	2076·59	343156·95	436,921	288,804,781	25·710	8·711
662	2079·73	344196·03	438,244	290,117,528	25·720	8·715
663	2082·88	345236·69	439,569	291,434,247	25·749	8·719
664	2086·02	346278·91	440,896	292,754,944	25·768	8·724
665	2089·16	347322·70	442,225	294,079,625	25·787	8·728
666	2092·30	348368·07	443,556	295,408,296	25·807	8·733
667	2095·44	349415·00	444,889	296,740,963	25·826	8·737
668	2098·58	350463·51	446,224	298,077,632	25·846	8·742
669	2101·73	351513·59	447,561	299,418,309	25·865	8·746

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670	2104·87	352565·24	448,900	300,763,000	25·884	8·750
671	2108·01	353618·43	450,241	302,111,711	25·904	8·753
672	2111·15	354673·24	451,584	303,464,448	25·923	8·759
673	2114·29	355729·60	452,929	304,821,217	25·942	8·763
674	2117·43	356787·54	454,276	306,182,024	25·961	8·768
675	2120·58	357847·04	455,625	307,546,875	25·981	8·772
676	2123·72	358908·11	456,976	308,915,776	26·000	8·776
677	2126·86	359970·75	458,329	310,288,733	26·019	8·781
678	2130·00	361034·97	459,684	311,665,752	26·038	8·785
679	2133·14	362100·75	461,041	313,046,839	26·058	8·789
680	2136·28	363168·11	462,400	314,432,000	26·077	8·794
681	2139·42	364237·04	463,761	315,821,241	26·096	8·798
682	2142·57	365307·54	465,124	317,214,568	26·115	8·802
683	2145·71	366379·60	466,489	318,611,987	26·134	8·807
684	2148·85	367453·24	467,856	320,013,504	26·153	8·811
685	2151·99	368528·45	469,225	321,419,125	26·172	8·815
686	2155·13	369605·23	470,596	322,828,856	26·192	8·819
687	2158·27	370683·59	471,969	324,242,703	26·211	8·824
688	2161·42	371763·51	473,344	325,660,672	26·229	8·828
689	2164·56	372845·00	474,721	327,082,769	26·249	8·832
690	2167·70	373928·07	476,100	328,509,000	26·268	8·836
691	2170·84	375012·70	477,481	329,939,371	26·287	8·841
692	2173·98	376098·91	478,864	331,373,888	26·306	8·845
693	2177·12	377186·68	480,249	332,812,557	26·325	8·849
694	2180·27	378276·03	481,636	334,255,384	26·344	8·853
695	2183·41	379366·95	483,025	335,702,375	26·363	8·858
696	2186·55	380459·44	484,416	337,153,536	26·382	8·862
697	2189·69	381553·50	485,809	338,608,873	26·401	8·866
698	2192·83	382649·43	487,204	340,068,392	26·419	8·870
699	2195·97	383746·33	488,601	341,532,099	26·439	8·875
700	2199·12	384845·10	490,000	343,000,000	26·457	8·879
701	2202·26	385945·44	491,401	344,472,101	26·476	8·883
702	2205·40	387047·36	492,804	345,948,088	26·495	8·887
703	2208·54	388150·84	494,209	347,428,927	26·514	8·892
704	2211·68	389255·90	495,616	348,913,664	26·533	8·896
705	2214·82	390362·52	497,025	350,402,625	26·552	8·900
706	2217·9	391470·32	498,436	351,895,816	26·571	8·904
707	2221·11	392580·49	499 849	353,393,243	26·589	8·908
708	2224·25	393691·83	501,264	354,894,912	26·608	8·913
709	2227·39	394804·74	502 681	356,400,829	26·627	8·917
710	2230·53	395919·21	504,100	357,911,000	26·644	8·921
711	2233·67	397035·27	505,521	359,425,431	26·664	8·925

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712	2236·81	398152·89	506,944	360,944,128	26·683	8·929
713	2239·96	399272·08	508,369	362,467,097	26·702	8·934
714	2243·10	400392·84	509,796	363,994,344	26·721	8·938
715	2246·24	401515·18	511,225	365,525,875	26·739	8·942
716	2249·38	402639·08	512,656	367,061,696	26·758	8·946
717	2252·52	403764·56	514,089	368,601,813	26·777	8·950
718	2255·66	404891·60	515,524	370,146,232	26·795	8·954
719	2258·81	406020·22	516,961	371,694,959	26·814	8·959
720	2261·95	407150·41	518,400	373,248,000	26·833	8·963
721	2265·09	408282·17	519,841	374,805,361	26·851	8·967
722	2268·23	409415·50	521,284	376,367,048	26·870	8·971
723	2271·37	410550·40	522,729	377,933,067	26·889	8·975
724	2274·51	411686·87	524,176	379,503,424	26·907	8·979
725	2277·66	412824·91	525,625	381,078,125	26·926	8·983
726	2280·80	413964·52	527,076	382,657,176	26·944	8·988
727	2283·94	415105·71	528,529	384,240,583	26·963	8·992
728	2287·08	416248·46	529,984	385,828,352	26·991	8·996
729	2290·22	417392·79	531,441	387,420,489	27·000	9·000
730	2293·36	418538·68	532,900	389,017,000	27·018	9·004
731	2296·50	419686·15	534,361	390,617,891	27·037	9·008
732	2299·65	420835·19	535,824	392,223,168	27·055	9·012
733	2302·79	421985·79	537,289	393,832,837	27·074	9·016
734	2305·93	423137·97	538,756	395,446,904	27·092	9·020
735	2309·07	424291·72	540,225	397,065,375	27·111	9·023
736	2312·21	425447·04	541,696	398,688,256	27·129	9·029
737	2315·35	426603·93	543,169	400,315,553	27·148	9·033
738	2318·50	427762·40	544,644	401,947,272	27·166	9·037
739	2321·64	428922·43	546,121	403,583,419	27·184	9·041
740	2324·78	430084·03	547,600	405,224,000	27·203	9·045
741	2327·92	431247·21	549,081	406,869,021	27·221	9·049
742	2331·06	432411·95	550,564	408,518,488	27·239	9·053
743	2334·20	433578·27	552,049	410,172,407	27·258	9·057
744	2337·35	434746·16	553,536	411,830,784	27·276	9·061
745	2340·49	435915·62	555,025	413,493,625	27·295	9·065
746	2343·63	437086·64	556,516	415,160,936	27·313	9·069
747	2346·77	438259·24	558,009	416,832,723	27·331	9·073
748	2349·91	439433·41	559,504	418,508,992	27·349	4·077
749	2353·05	440609·16	561,001	420,189,749	27·368	9·081
750	2356·20	441786·47	562,500	421,875,000	27·386	9·086
751	2359·34	442965·35	564,001	423,564,751	27·404	9·089
752	2362·48	444145·80	565,504	424,525,900	27·423	9·094
753	2365·62	445327·83	567,009	426,957,777	27·441	9·098

Square.	Cube.	Square Root.	Cube Root.
702,244	588,480,472	28·948	9·42
703,921	590,589,719	28·965	9·432
705,600	592,704,000	28·983	9·435
707,281	594,823,321	29·000	9·439
708,964	596,947,688	29·017	9·443
710,649	599,077,107	29·034	9·447
712,336	601,211,584	29·052	9·450
714,025	603,351,125	29·069	9·454
715,716	605,495,736	29·086	9·458
717,409	607,645,423	29·103	9·461
719,104	609,800,192	29·120	9·465
720,801	611,960,049	29·138	9·469
722,500	614,125,000	29·155	9·473
724,201	616,295,051	29·172	9·476
725,904	618,470,208	29·189	9·480
727,609	620,650,477	29·206	9·483
729,316	622,835,864	29·223	9·487
731,025	625,026,375	29·240	9·491
732,736	627,222,016	29·257	9·495
734,449	629,422,793	29·274	9·499
736,164	631,628,712	29·292	9·502
737,881	633,839,779	29·309	9·506
739,600	636,056,000	29·326	9·509
741,321	638,277,381	29·343	9·513
743,044	640,503,928	29·360	9·517
744,769	642,735,647	29·377	9·520
746,496	644,972,544	29·394	9·524
748,225	647,214,625	29·411	9·528
749,956	649,461,896	29·428	9·532
751,689	651,714,363	29·445	9·535
753,424	653,972,032	29·462	9·539
755,161	656,234,909	29·479	9·543
756,900	658,503,000	29·496	9·546
758,641	660,776,311	29·513	9·550
760,384	663,054,848	29·529	9·554
762,129	665,338,617	29·546	9·557
763,876	667,627,624	29·563	9·561
765,625	669,921,875	29·580	9·565
767,376	672,221,376	29·597	9·568
769,129	674,526,133	29·614	9·572
770,884	676,836,152	29·631	9·575
772,641	679,151,439	29·648	9·579

No. or Diam.	Circumference.	Circular Area.	Square.	Cube.	Square Root.	Cube Root.
880	2764·60	608212·34	774,400	681,472,000	29·665	9·583
881	2767·74	609595·42	776,161	683,797,841	29·682	9·586
882	2770·89	610980·08	777,924	686,128,968	29·698	9·590
883	2774·03	612366·31	779,689	688,465,387	29·715	9·594
884	2777·17	613754·11	781,456	690,807,104	29·732	9·597
885	2780·31	615143·48	783,225	693,154,125	29·749	9·601
886	2783·45	616534·42	784,996	695,506,456	29·766	9·604
887	2786·59	617926·93	786,769	697,864,103	29·782	9·608
888	2789·73	619321·01	788,544	700,227,072	29·799	9·612
889	2792·88	620716·66	790,321	702,595,369	29·816	9·615
890	2796·02	622113·89	792,100	704,969,000	29·833	9·619
891	2799·16	623512·68	793,881	707,347,971	29·850	9·623
892	2802·30	624913·04	795,664	709,732,288	29·866	9·626
893	2805·44	626314·98	797,449	712,121,957	29·883	9·630
894	2808·58	627718·49	799,236	714,516,984	29·900	9·633
895	2811·73	629123·56	801,025	716,917,375	29·916	9·637
896	2814·87	630530·21	802,816	719,323,136	29·933	9·640
897	2818·01	631938·43	804,609	721,734,273	29·950	9·644
898	2821·15	633348·22	806,404	724,150,792	29·967	9·648
899	2824·29	634759·58	808,201	726,572,699	29·983	9·651
900	2827·43	636172·51	810,000	729,000,000	30·000	9·655
901	2830·58	637587·01	811,804	731,432,701	30·017	9·658
902	2833·72	639003·09	813,604	733,870,808	30·033	9·662
903	2836·86	640420·73	815,409	736,314,327	30·050	9·666
904	2840·00	641839·95	817,216	738,763,264	30·066	9·669
905	2843·14	643260·73	819,025	741,217,625	30·083	9·673
906	2846·28	644683·09	820,836	743,677,416	30·100	9·676
907	2849·43	646107·01	822,649	746,142,643	30·116	9·680
908	2852·57	647532·51	824,464	748,613,312	30·133	9·683
909	2855·71	648959·58	826,281	751,089,429	30·150	9·687
910	2858·85	650388·21	828,100	753,571,000	30·163	9·690
911	2861·99	651818·43	829,921	756,058,031	30·183	9·694
912	2865·13	653250·21	831,744	758,550,528	30·199	9·698
913	2868·27	654683·56	833,569	761,048,497	30·216	9·701
914	2871·42	656118·48	835,396	763,551,944	30·232	9·705
915	2874·56	657554·98	837,225	766,060,875	30·249	9·708
916	2877·70	658993·04	839,056	768,575,296	30·265	9·712
917	2880·84	660432·68	840,889	771,095,213	30·282	9·715
918	2883·98	661873·88	842,724	773,620,632	30·298	9·718
919	2887·12	663316·66	844,561	776,151,559	30·315	9·722
920	2890·27	664761·01	846,400	778,688,000	30·331	9·726
921	2893·41	666206·92	848,241	781,229,961	30·348	9·729

No. or Diam.	Circumference.	Circular Area.	Square.	Cube.	Square Root.	Cube Root.
838	2632·64	551541·15	702,244	588,480,472	28·948	9·428
839	2635·80	552858·26	703,921	590,589,719	28·965	9·432
840	2638·94	554176·94	705,600	592,704,000	28·983	9·435
841	2642·08	555497·20	707,281	594,823,321	29·000	9·439
842	2645·22	556819·02	708,964	596,947.688	29·017	9·443
843	2648·36	558142·42	710,649	599,077,107	29·034	9·447
844	2651·50	559467·39	712,336	601,211,584	29·052	9·450
845	2654·65	560793·92	714,025	603,351,125	29·069	9·454
846	2657·79	562122·03	715,716	605,495.736	29·086	9·458
847	2660·93	563451·71	717,409	607,645,423	29·103	9·461
848	2664·07	564782·96	719,104	609.800,192	29·120	9·465
849	2667·21	566115·78	720,801	611,960,049	29·138	9·469
850	2670·35	567450·17	722.500	614,125,000	29·155	9·473
851	2673·50	568786·14	724,201	616,295,051	29·172	9·476
852	2676·64	570123·67	725,904	618,470,208	29·189	9·480
853	2679·78	571462·77	727,609	620,650,477	29·206	9·483
854	2682·92	572803·45	729,316	622,835,864	29·223	9·487
855	2686·06	574145·69	731,025	625,026,375	29·240	9·491
856	2689·20	575489·51	732,736	627,222.016	29·257	9·495
857	2692·35	576834·90	734.449	629,422,793	29·274	9·499
858	2695·49	578181·85	736.164	631,628,712	29·292	9·502
859	2698·63	579530·38	737.881	633,839.779	29·309	9·506
860	2701·77	580880·48	739,600	636,056,000	29·326	9·509
861	2704·91	582232·15	741.321	638.277,381	29·343	9·513
862	2708·05	583585·39	743,044	640.503,928	29·360	9·517
863	2711·19	584940·21	744,769	642,735,647	29·377	9·520
864	2714·34	586296·59	746.496	644,972,544	29·394	9·524
865	2717·45	587654·54	748.225	647,214,625	29·411	9·528
866	2720·62	589014·07	749,956	749,461,896	29·428	9·532
867	2723·76	590375·16	751,689	651,714,363	29·445	9·535
868	2726·90	591737·83	753,424	653,972,032	29·462	9·539
869	2730·04	593102·06	755,161	656.234.909	29·479	9·543
870	2733·19	594467·87	756,900	658,503,000	29·496	9·546
871	2736·33	595835·25	758,641	660,776,311	29·513	9·550
872	2739·47	597204·20	760,384	663,054,848	29·529	9·554
873	2742·61	598574·72	762.129	665,338,617	29·546	9·557
874	2745·75	599946·81	763,876	667,627,624	29·563	9·561
875	2748·89	601320·47	765,625	669,921,875	29·580	9·565
876	2752·04	602695·70	767,376	672.221,376	29·597	9·568
877	2755·18	604072·50	769,129	674,526,133	29·614	9·572
878	2758·32	605450·88	770,884	676,836,152	29·631	9·575
879	2761·46	606830·82	772,641	679.151.439	29·648	9·579

No. or Diam.	Circumference.	Circular Area.	Square.	Cube.	Square Root.	Cube Root.
880	2764·60	608212·34	774,400	681,472,000	29·665	9·583
881	2767·74	609595·42	776,161	683,797,841	29·682	9·586
882	2770·89	610980·08	777,924	686,128,968	29·698	9·590
883	2774·03	612366·31	779,689	688,465,387	29·715	9·594
884	2777·17	613754·11	781,456	690,807,104	29·732	9·597
885	2780·31	615143·48	783,225	693,154,125	29·749	9·601
886	2783·45	616534·42	784,996	695,506,456	29·766	9·604
887	2786·59	617926·93	786,769	697,864,103	29·782	9·608
888	2789·73	619321·01	788,544	700,227,072	29·799	9·612
889	2792·88	620716·66	790,321	702,595,369	29·816	9·615
890	2796·02	622113·89	792,100	704,969,000	29·833	9·619
891	2799·16	623512·68	793,881	707,347,971	29·850	9·623
892	2802·30	624913·04	795,664	709,732,288	29·866	9·626
893	2805·44	626314·98	797,449	712,121,957	29·883	9·630
894	2808·58	627718·49	799,236	714,516,984	29·900	9·633
895	2811·73	629123·56	801,025	716,917,375	29·916	9·637
896	2814·87	630530·21	802,816	719,323,136	29·933	9·640
897	2818·01	631938·43	804,609	721,734,273	29·950	9·644
898	2821·15	633348·22	806,404	724,150,792	29·967	9·648
899	2824·29	634759·58	808,201	726,572,699	29·983	9·651
900	2827·43	636172·51	810,000	729,000,000	30·000	9·655
901	2830·58	637587·01	811,804	731,432,701	30·017	9·658
902	2833·72	639003·09	813,604	733,870,808	30·033	9·662
903	2836·86	640420·73	815,409	736,314,327	30·050	9·666
904	2840·00	641839·95	817,216	738,763,264	30·066	9·669
905	2843·14	643260·73	819,025	741,217,625	30·083	9·673
906	2846·28	644683·09	820,836	743,677,416	30·100	9·676
907	2849·43	646107·01	822,649	746,142,643	30·116	9·680
908	2852·57	647532·51	824,464	748,613,312	30·133	9·683
909	2855·71	648959·58	826,281	751,089,429	30·150	9·687
910	2858·85	650388·21	828,100	753,571,000	30·163	9·690
911	2861·99	651818·43	829,921	756,058,031	30·183	9·694
912	2865·13	653250·21	831,744	758,550,528	30·199	9·698
913	2868·27	654683·56	833,569	761,048,497	30·216	9·701
914	2871·42	656118·48	835,396	763,551,944	30·232	9·705
215	2874·56	657554·98	837,225	766,060,875	30·249	9·708
916	2877·70	658993·04	839,056	768,575,296	30·265	9·712
917	2880·84	660432·68	840,889	771,095,213	30·282	9·715
918	2883·98	661873·88	842,724	773,620,632	30·298	9·718
919	2887·12	663316·66	844,561	776,151,559	30·315	9·722
920	2890·27	664761·01	846,400	778,688,000	30·331	9·726
921	2893·41	666206·92	848,241	781,229,961	30·348	9·729

No. or Diam.	Circumference.	Circular Area.	Square.	Cube.	Square Root.	Cube Root.
838	2632·64	551541·15	702,244	588,480,472	28·948	9·428
839	2635·80	552858·26	703,921	590,589,719	28·965	9·432
840	2638·94	554176·94	705,600	592,704,000	28·983	9·435
841	2642·08	555497·20	707,281	594,823,321	29·000	9·439
842	2645·22	556819·02	708,964	596,947,688	29·017	9·443
843	2648·36	558142·42	710,649	599,077,107	29·034	9·447
844	2651·50	559467·39	712,336	601,211,584	29·052	9·450
845	2654·65	560793·92	714,025	603,351,125	29·069	9·454
846	2657·79	562122·03	715,716	605,495,736	29·086	9·458
847	2660·93	563451·71	717,409	607,645,423	29·103	9·461
848	2664·07	564782·96	719,104	609,800,192	29·120	9·465
849	2667·21	566115·78	720,801	611,960,049	29·138	9·469
850	2670·35	567450·17	722,500	614,125,000	29·155	9·473
851	2673·50	568786·14	724,201	616,295,051	29·172	9·476
852	2676·64	570123·67	725,904	618,470,208	29·189	9·480
853	2679·78	571462·77	727,609	620,650,477	29·206	9·483
854	2682·92	572803·45	729,316	622,835,864	29·223	9·487
855	2686·06	574145·69	731,025	625,026,375	29·240	9·491
856	2689·20	575489·51	732,736	627,222,016	29·257	9·495
857	2692·35	576834·90	734,449	629,422,793	29·274	9·499
858	2695·49	578181·85	736,164	631,628,712	29·292	9·502
859	2698·63	579530·38	737,881	633,839,779	29·309	9·506
860	2701·77	580880·48	739,600	636,056,000	29·326	9·509
861	2704·91	582232·15	741,321	638,277,381	29·343	9·513
862	2708·05	583585·39	743,044	640,503,928	29·360	9·517
863	2711·19	584940·21	744,769	642,735,647	29·377	9·520
864	2714·34	586296·59	746,496	644,972,544	29·394	9·524
865	2717·45	587654·54	748,225	647,214,625	29·411	9·528
866	2720·62	589014·07	749,956	749,461,896	29·428	9·532
867	2723·76	590375·16	751,689	651,714,363	29·445	9·535
868	2726·90	591737·83	753,424	653,972,032	29·462	9·539
869	2730·04	593102·06	755,161	656,234,909	29·479	9·543
870	2733·19	594467·87	756,900	658,503,000	29·496	9·546
871	2736·33	595835·25	758,641	660,776,311	29·513	9·550
872	2739·47	597204·20	760,384	663,054,848	29·529	9·554
873	2742·61	598574·72	762,129	665,338,617	29·546	9·557
874	2745·75	599946·81	763,876	667,627,624	29·563	9·561
875	2748·89	601320·47	765,625	669,921,875	29·580	9·565
876	2752·04	602695·70	767,376	672,221,376	29·597	9·568
877	2755·18	604072·50	769,129	674,526,133	29·614	9·572
878	2758·32	605450·88	770,884	676,836,152	29·631	9·575
879	2761·46	606830·82	772,641	679,151,439	29·648	9·579

No. or Diam.	Circumference.	Circular Area.	Square.	Cube.	Square Root.	Cube Root
880	2764·60	608212·34	774,400	681,472,000	29·665	9·583
881	2767·74	609595·42	776,161	683,797,841	29·682	9·586
882	2770·89	610980·08	777,924	686,128,968	29·698	9·590
883	2774·03	612366·31	779,689	688,465.387	29·715	9·594
884	2777·17	613754·11	781,456	690,807,104	29·732	9·597
885	2780·31	615143·48	783,225	693,154,125	29·749	9·601
886	2783·45	616534·42	784,996	695,506,456	29·766	9·604
887	2786·59	617926·93	786,769	697,864,103	29·782	9·608
888	2789·73	619321·01	788,544	700,227,072	29·799	9·612
889	2792·88	620716·66	790,321	702,595,369	29·816	9·615
890	2796·02	622113·89	792,100	704,969.000	29·833	9·619
891	2799·16	623512·68	793,881	707,347,971	29·850	9·623
892	2802·30	624913·04	795,664	709,732.288	29·866	9·626
893	2805·44	626314·98	797,449	712,121.957	29·883	9·630
894	2808·58	627718·49	799.236	714,516.984	29·900	9·633
895	2811·73	629123·56	801,025	716,917.375	29·916	9·637
896	2814·87	630530·21	802,816	719,323,136	29·933	9·640
897	2818·01	631938·43	804,609	721,734,273	29·950	9·644
898	2821·15	633348·22	806,404	724,150.792	29·967	9·648
899	2824·29	634759·58	808,201	726,572,699	29·983	9·651
900	2827·43	636172·51	810.000	729.000,000	30·000	9·655
901	2830·58	637587·01	811.804	731,432,701	30·017	9·658
902	2833·72	639003·09	813,604	733,870,808	30·033	9·662
903	2836·86	640420·73	815.409	736,314,327	30·050	9·666
904	2840·00	641839·95	817,216	738.763,264	30·066	9·669
905	2843·14	643260·73	819,025	741,217,625	30·083	9·673
906	2846·28	644683·09	820,836	743,677,416	30·100	9·676
907	2849·43	646107·01	822,649	746,142,643	30·116	9·680
908	2852·57	647532·51	824,464	748.613,312	30·133	9·683
909	2855·71	648959·58	826,281	751,089,429	30·150	9·687
910	2858·85	650388·21	828,100	753,571,000	30·163	9·690
911	2861·99	651818·43	829,921	756,058,031	30·183	9·694
912	2865·13	653250·21	831,744	758,550,528	30·199	9·698
913	2868·27	654683·56	833,569	761,048,497	30·216	9·701
914	2871·42	656118·48	835,396	763,551,944	30·232	9·705
215	2874·56	657554·98	837,225	766,060,875	30·249	9·708
916	2877·70	658993·04	839,056	768.575,296	30·265	9·712
917	2880·84	660432·68	840;889	771,095.213	30·282	9·715
918	2883·98	661873·88	842,724	773,620,632	30·298	9·718
919	2887·12	663316·66	844,561	776,151,559	30·315	9·722
920	2890·27	664761·01	846,400	778,688,000	30·331	9·726
921	2893·41	666206·92	848,241	781.229,961	30·348	9·729

No. or Diam.	Circumference.	Circular Area.	Square.	Cube.	Square Root.	Cube Root.
922	2896·55	667654·41	850,084	783,777,448	30·364	9·733
923	2899·69	669103·47	851,929	786,330,467	30·381	9·736
924	2902·83	670554·10	853,776	788,889,024	30·397	9·740
925	2905·97	672006·30	855,625	791,453,125	30·414	9·743
926	2909·12	673460·08	857,476	794,022,776	30·430	9·747
927	2912·26	674915·42	859,329	796,597,983	30·447	9·750
928	2915·40	676372·33	861,184	799,178,752	30·463	9·754
929	2918·54	677830·82	863,041	801,765,089	30·479	9·757
930	2921·68	679290·87	864,900	804,357,000	30·496	9·761
931	2924·82	680752·50	866,761	806,954,491	30·512	9·764
932	2927·96	682215·69	868,624	809,557,568	30·529	9·768
933	2931·11	683680·46	870,489	812,166,237	30·545	9·771
934	2934·25	685146·80	872,356	814,780,504	30·561	9·775
935	2937·39	686614·71	874,225	817,400,375	30·578	9·778
936	2940·53	688084·19	876,096	820,025,856	30·594	9·783
937	2943·67	689555·24	877,969	822,656,953	30·610	9·785
938	2946·81	691027·86	879,844	825,293,672	30·627	9·789
939	2949·96	692502·05	881.721	827,936,019	30·643	9·792
940	2953·10	693977·82	883,600	830,584,000	30·659	9·796
941	2956·24	695455·15	885.481	833,237,621	30·676	9·799
942	2959·38	696934·06	887,364	835,896,888	30·692	9·803
943	2962·52	698414·53	889,249	838,561,807	30·708	9·806
944	2965·66	699896·58	891,136	841,232,384	30·724	9·810
945	2968·81	701380·28	893,025	843,908,625	30·741	9·813
946	2971·95	702865·38	894,916	846,590,536	30·757	9·817
947	2975·09	704352·14	896,809	849,278,123	30·773	9·820
948	2978·23	705840·47	898,704	851,971,392	30·790	9·823
949	2981·37	707330·37	900,601	854,670,349	30·806	9·827
950	2984·51	708821·84	902,500	857,375,000	30·822	9·830
951	2987·66	710314·88	904,401	860,085,351	30·838	9·834
952	2990·80	711809·58	906,304	862,801,408	30·854	9·837
953	2993·94	713305·68	908,209	865,523,177	30·871	9·841
954	2997·08	714803·48	910,116	868,250,664	30·887	9·844
955	3000·22	716302·76	912,025	870,983,875	30·903	9·848
956	3003·36	717803·66	913,936	873,722,816	30·919	9·851
957	3006·50	719306·12	915,849	876,467,493	30·935	9·854
958	3009·65	720810·16	917,764	879,217,912	30·951	9·858
959	3012·79	722315·77	919,681	881,974,079	30·968	9·861
960	3015·93	723822·95	921,600	884,736,000	30·984	9·865
961	3019·07	725331·70	923,521	887.503,681	31·000	9·868
962	3022·21	726842·02	925,444	890,277,128	31·016	9·872
963	3025·35	728353·91	927,369	893,056,347	31·032	9·875

No. or Diam.	Circumference.	Circular Area.	Square.	Cube.	Square Root.	Cube Root.
964	3028·50	729867·37	929,296	895,841,344	31·048	9·878
965	3031·64	731382·40	931,225	898,632,125	31·064	9·881
966	3034·78	732899·01	933,156	901,428,696	31·080	9·885
967	3037·92	734417·18	935,089	904,231,063	31·097	9·889
968	3041·06	735936·93	937,024	907,039,232	31·113	9·892
969	3044·20	737458·25	938,961	909,853,209	31·129	9·895
970	3047·35	738981·13	940,900	912,673,000	31·145	9·899
971	3050·49	740505·59	942,841	915,498,611	31·161	9·902
972	3053·63	742031·62	944,784	918,330,048	31·177	9·906
973	3056·77	743559·22	946,729	921,167,317	31·193	9·909
974	3059·91	745088·39	948,676	924,010,424	31·209	9·912
975	3063·05	746619·13	950,625	926,859,375	31·225	9·916
976	3066·19	748151·44	952,576	929,714,176	31·241	9·919
977	3069·34	749685·32	954,529	932,574,833	31·257	9·923
978	3072·48	751220·78	956,484	935,441,352	31·273	9·926
979	3075·62	752757·80	958,441	438,313,739	31·289	9·929
980	3078·76	754296·40	960,400	941,192,000	31·305	9·933
981	3081·90	755836·56	962,361	944,076,141	31·321	9·936
982	3085·04	757378·30	964,324	946,966,168	31·337	9·940
983	3088·19	758921·61	966,289	949,862,087	31.353	9·943
984	3091·33	760466·48	968,256	952,763,904	31·369	9·946
985	3094·47	762012·93	970,225	955,671,625	31·385	9·950
986	3097·61	763560·95	972,196	958,585,256	31·401	9·953
987	3100·75	765110·54	974,169	961,504,803	31·416	9·956
988	3103·89	766661·71	976,144	964,430,272	31·432	9·960
989	3107·04	768214·44	978,121	967,361,669	31·448	9·963
990	3110·18	769768·74	980,100	970,299,000	31·464	9·966
991	3113·32	771324·61	982,081	973,242,271	31·480	9·970
992	3116·46	772882·06	984,064	976,191,488	31·496	9·973
993	3119·60	774441·07	986,049	979,146,657	31·512	9·977
994	3122·74	776001·66	988,036	982,107,784	31·528	9·980
995	3125·89	777563·82	990,025	985,074,875	31·544	9·983
996	3129·03	779127·54	992,016	988,047,936	31·559	9·987
997	3132·17	780692·84	994,009	991,026,973	31·575	9·990
998	3135·31	782259·71	996,004	994,011,992	31·591	9·993
999	3138·45	783828·15	998,001	997,002,999	31·607	9·997
1000	3141·60	785398·16	1,000,000	1,000,000,000	31·623	10·000

TABLE 2.—CIRCLES: DIAMETER (FROM $\frac{1}{16}$ TO 120), CIRCUMFERENCE, AND AREA.*

Diameter.	Circumference.	Area.	Diameter.	Circumference.	Area.
$\frac{1}{16}$	·1963	·00307	$2\frac{9}{16}$	8·0503	5·1573
$\frac{1}{8}$	·3927	·01227	$2\frac{5}{8}$	8·2467	5·4119
$\frac{3}{16}$	·5890	·02761	$2\frac{11}{16}$	8·4430	5·6723
$\frac{1}{4}$	·7854	·04909	$2\frac{3}{4}$	8·6394	5·9395
$\frac{5}{16}$	·9817	·07670	$2\frac{13}{16}$	8·8357	6·2126
$\frac{3}{8}$	1·1781	·1104	$2\frac{7}{8}$	9·0321	6·4918
$\frac{7}{16}$	1·3744	·1503	$2\frac{15}{16}$	9·2284	6·7772
$\frac{1}{2}$	1·5708	·1963	3	9·4248	7·0686
$\frac{9}{16}$	1·7771	·2485	$3\frac{1}{16}$	9·6211	7·3662
$\frac{5}{8}$	1·9635	·3068	$3\frac{1}{8}$	9·8175	7·6699
$\frac{11}{16}$	2·1598	·3712	$3\frac{3}{16}$	10·014	7·9798
$\frac{3}{4}$	2·3562	·4417	$3\frac{1}{4}$	10·210	8·2957
$\frac{13}{16}$	2·5525	·5185	$3\frac{5}{16}$	10·406	8·6180
$\frac{7}{8}$	2·7489	·6013	$3\frac{3}{8}$	10·602	8·9462
$\frac{15}{16}$	2·9452	·6903	$3\frac{7}{16}$	10·799	9·2807
1	3·1416	·7854	$3\frac{1}{2}$	10·995	9·6211
$1\frac{1}{16}$	3·3379	·8866	$3\frac{9}{16}$	11·191	9·9680
$1\frac{1}{8}$	3·5343	·9940	$3\frac{5}{8}$	11·388	10·320
$1\frac{3}{16}$	3·7306	1·1075	$3\frac{11}{16}$	11·584	10·679
$1\frac{1}{4}$	3·9270	1·2271	$3\frac{3}{4}$	11·781	11·044
$1\frac{5}{16}$	4·1233	1·3530	$3\frac{13}{16}$	11·977	11·416
$1\frac{3}{8}$	4·3197	1·4848	$3\frac{7}{8}$	12·173	11·793
$1\frac{7}{16}$	4·5160	1·6229	$3\frac{15}{16}$	12·369	12·177
$1\frac{1}{2}$	4·7124	1·7671	4	12·566	12·566
$1\frac{9}{16}$	4·9087	1·9175	$4\frac{1}{16}$	12·762	12·962
$1\frac{5}{8}$	5·1051	2·0739	$4\frac{1}{8}$	12·959	13·364
$1\frac{11}{16}$	5·3014	2·2365	$4\frac{3}{16}$	13·155	13·772
$1\frac{3}{4}$	5·4978	2·4052	$4\frac{1}{4}$	13·351	14·186
$1\frac{13}{16}$	5·6941	2·5800	$4\frac{5}{16}$	13·547	14·606
$1\frac{7}{8}$	5·8905	2·7611	$4\frac{3}{8}$	13·744	15·033
$1\frac{15}{16}$	6·0868	2·9483	$4\frac{7}{16}$	13·940	15·465
2	6·2832	3·1416	$4\frac{1}{2}$	14·137	15·904
$2\frac{1}{16}$	6·4795	3·3380	$4\frac{9}{16}$	14·333	16·349
$2\frac{1}{8}$	6·6759	3·5465	$4\frac{5}{8}$	14·529	16·800
$2\frac{3}{16}$	6·8722	3·7584	$4\frac{11}{16}$	14·725	17·257
$2\frac{1}{4}$	7·0686	3·9760	$4\frac{3}{4}$	14·922	17·720
$2\frac{5}{16}$	7·2649	4·2000	$4\frac{13}{16}$	15·119	18·190
$2\frac{3}{8}$	7·4613	4·4302	$4\frac{7}{8}$	15·315	18·665
$2\frac{7}{16}$	7·6576	4·7066	$4\frac{15}{16}$	15·511	19·147
$2\frac{1}{2}$	7·8540	4·9087	5	15·708	19·635

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Diameter.	Circumference.	Area.	Diameter.	Circumference.	Area.
$5\frac{1}{16}$	15·904	20·129	$9\frac{3}{8}$	29·452	69·029
$5\frac{1}{8}$	16·100	20·629	$9\frac{1}{2}$	29·845	70·882
$5\frac{3}{16}$	16·296	21·135	$9\frac{5}{8}$	30·237	72·759
$5\frac{1}{4}$	16·493	21·647	$9\frac{3}{4}$	30·630	74·662
$5\frac{5}{16}$	16·689	22·166	$9\frac{7}{8}$	31·023	76·588
$5\frac{3}{8}$	16·886	22·690	10	31·416	78·540
$5\frac{7}{16}$	17·082	23·221	$10\frac{1}{8}$	31·808	80·515
$5\frac{1}{2}$	17·278	23·758	$10\frac{1}{4}$	32·201	82·516
$5\frac{9}{16}$	17·474	24·301	$10\frac{3}{8}$	32·594	84·540
$5\frac{5}{8}$	17·671	24·850	$10\frac{1}{2}$	32·986	86·590
$5\frac{11}{16}$	17·867	25·406	$10\frac{5}{8}$	33·379	88·664
$5\frac{3}{4}$	18·064	25·967	$10\frac{3}{4}$	33·772	90·762
$5\frac{13}{16}$	18·261	26·535	$10\frac{7}{8}$	34·164	92·885
$5\frac{7}{8}$	18·457	27·108	11	34·558	95·033
$5\frac{15}{16}$	18·653	27·688	$11\frac{1}{8}$	34·950	97·205
6	18·849	28·274	$11\frac{1}{4}$	35·343	99·402
$6\frac{1}{8}$	19·242	29·464	$11\frac{3}{8}$	35·735	101·623
$6\frac{1}{4}$	19·635	30·679	$11\frac{1}{2}$	36·128	103·869
$6\frac{3}{8}$	20·027	31·919	$11\frac{5}{8}$	36·521	106·139
$6\frac{1}{2}$	20·420	33·183	$11\frac{3}{4}$	36·913	108·434
$6\frac{5}{8}$	20·813	34·471	$11\frac{7}{8}$	37·306	110·753
$6\frac{3}{4}$	21·205	35·784	12	37·699	113·097
$6\frac{7}{8}$	21·598	37·122	$12\frac{1}{8}$	38·091	115·466
7	21·991	38·484	$12\frac{1}{4}$	38·484	117·859
$7\frac{1}{8}$	22·383	39·871	$12\frac{3}{8}$	38·877	120·276
$7\frac{1}{4}$	22·776	41·282	$12\frac{1}{2}$	39·270	122·718
$7\frac{3}{8}$	23·169	42·718	$12\frac{5}{8}$	39·662	125·184
$7\frac{1}{2}$	23·562	44·178	$12\frac{3}{4}$	40·055	127·676
$7\frac{5}{8}$	23·954	45·663	$12\frac{7}{8}$	40·448	130·192
$7\frac{3}{4}$	24·347	47·173	13	40·840	132·732
$7\frac{7}{8}$	24·740	48·707	$13\frac{1}{8}$	41·233	135·297
8	25·132	50·265	$13\frac{1}{4}$	41·626	137·886
$8\frac{1}{8}$	25·515	51·848	$13\frac{3}{8}$	42·018	140·500
$8\frac{1}{4}$	25·918	53·456	$13\frac{1}{2}$	42·411	143·139
$8\frac{3}{8}$	26·310	55·088	$13\frac{5}{8}$	42·804	145·802
$8\frac{1}{2}$	26·703	56·745	$13\frac{3}{4}$	43·197	148·489
$8\frac{5}{8}$	27·096	58·426	$13\frac{7}{8}$	43·589	151·201
$8\frac{3}{4}$	27·489	60·132	14	43·982	153·938
$8\frac{7}{8}$	27·881	61·862	$14\frac{1}{8}$	44·375	156·699
9	28·274	63·617	$14\frac{1}{4}$	44·767	159·485
$9\frac{1}{8}$	28·667	65·396	$14\frac{3}{8}$	45·160	162·295
$9\frac{1}{4}$	29·059	67·200	$14\frac{1}{2}$	45·553	165·130

Diameter.	Circumference.	Area.	Diameter.	Circumference.	Area.
14⅝	45·945	167·989	**19⅞**	62·439	310·245
14¾	46·338	170·873	**20**	62·832	314·160
14⅞	46·731	173·782	**20⅛**	63·224	318·099
15	47·124	176·715	**20¼**	63·617	322·063
15⅛	47·516	179·672	**20⅜**	64·010	326·051
15¼	47·909	182·654	**20½**	64·402	330·064
15⅜	48·302	185·661	**20⅝**	64·795	334·101
15½	48·694	188·692	**20¾**	65·188	338·163
15⅝	49·087	191·748	**20⅞**	65·580	342·250
15¾	49·480	194·828	**21**	65·973	346·361
15⅞	49·872	197·933	**21⅛**	66·366	350·497
16	50·265	201·062	**21¼**	66·759	354·657
16⅛	50·658	204·216	**21⅜**	67·151	358·841
16¼	51·051	207·394	**21½**	67·544	363·051
16⅜	51·443	210·597	**21⅝**	67·937	367·284
16½	51·836	213·825	**21¾**	68·329	371·543
16⅝	52·229	217·077	**21⅞**	68·722	375·826
16¾	52·621	220·353	**22**	69·115	380·133
16⅞	53·014	223·654	**22⅛**	69·507	384·465
17	53·407	226·980	**22¼**	69·900	388·822
17⅛	53·799	230·330	**22⅜**	70·293	393·203
17¼	54·192	233·705	**22½**	70·686	397·608
17⅜	54·585	237·104	**22⅝**	71·078	402·038
17½	54·978	240·528	**22¾**	71·471	406·493
17⅝	55·370	243·977	**22⅞**	71·864	410·972
17¾	55·763	247·450	**23**	72·256	415·476
17⅞	56·156	250·947	**23⅛**	72·649	420·004
18	56·548	254·469	**23¼**	73·042	424·557
18⅛	56·941	258·016	**23⅜**	73·434	429·135
18¼	57·334	261·587	**23½**	73·827	433·731
18⅜	57·726	265·182	**23⅝**	74·220	438·363
18½	58·119	268·803	**23¾**	74·613	443·014
18⅝	58·512	272·447	**23⅞**	75·005	447·699
18¾	58·905	276·117	**24**	75·398	452·390
18⅞	59·297	279·811	**24⅛**	75·791	457·115
19	59·690	283·529	**24¼**	76·183	461·864
19⅛	60·083	287·272	**24⅜**	76·576	466·638
19¼	60·475	291·039	**24½**	76·969	471·436
19⅜	60·868	294·831	**24⅝**	77·361	476·259
19½	61·261	298·648	**24¾**	77·754	481·106
19⅝	61·653	302·489	**24⅞**	78·147	485·978
19¾	62·046	306·355	**25**	78·540	490·875

Diameter.	Circumference.	Area.	Diameter.	Circumference.	Area.
25⅛	78·932	495·796	**30⅜**	95·426	724·641
25¼	79·325	500·741	**30½**	95·818	730·618
25⅜	79·718	505·711	**30⅝**	96·211	736·619
25½	80·110	510·706	**30¾**	96·604	742·644
25⅝	80·503	515·725	**30⅞**	96·996	748·694
25¾	80·896	520·769	**31**	97·389	754·769
25⅞	81·288	525·837	**31⅛**	97·782	760·868
26	81·681	530·930	**31¼**	98·175	766·992
26⅛	82·074	536·047	**31⅜**	98·567	773·140
26¼	82·467	541·189	**31½**	98·968	779·313
26⅜	82·859	546·356	**31⅝**	99·353	785·510
26½	83·252	551·547	**31¾**	99·745	791·732
26⅝	83·645	556·762	**31⅞**	100·138	797·978
26¾	84·037	562·002	**32**	100·531	804·249
26⅞	84·430	567·267	**32⅛**	100·924	810·545
27	84·823	572·556	**32¼**	101·316	816·865
27⅛	85·215	577·870	**32⅜**	101·709	823·209
27¼	85·608	583·208	**32½**	102·102	829·578
27⅜	86·001	588·571	**32⅝**	102·494	835·972
27½	86·394	593·958	**32¾**	102·887	842·390
27⅝	86·786	599·370	**32⅞**	103·280	848·833
27¾	87·179	604·807	**33**	103·672	855·30
27⅞	87·572	610·268	**33⅛**	104·055	861·79
28	87·964	615·753	**33¼**	104·458	868·30
28⅛	88·357	621·263	**33⅜**	104·850	874·84
28¼	88·750	626·798	**33½**	105·243	881·41
28⅜	89·142	632·357	**33⅝**	105·636	888·00
28½	89·535	637·941	**33¾**	106·029	894·61
28⅝	89·928	643·594	**33⅞**	106·421	901·25
28¾	90·321	649·182	**34**	106·814	907·92
28⅞	90·713	654·839	**34⅛**	107·207	914·61
29	91·106	660·521	**34¼**	107·599	921·32
29⅛	91·499	666·227	**34⅜**	107·992	928·06
29¼	91·891	671·958	**34½**	108·385	934·82
29⅜	92·284	677·714	**34⅝**	108·777	941·60
29½	92·677	683·494	**34¾**	109·170	948·41
29⅝	93·069	689·298	**34⅞**	109·563	955·25
29¾	93·462	695·128	**35**	109·956	962·11
29⅞	93·855	700·981	**35⅛**	110·348	968·99
30	94·248	706·860	**35¼**	110·741	975·90
30⅛	94·640	712·762	**35⅜**	111·134	982·84
30¼	95·033	718·690	**35½**	111·526	989·80

TABLE 2.—CIRCLES: DIAMETER (FROM $\frac{1}{16}$ TO 120), CIRCUMFERENCE, AND AREA.*

Diameter.	Circumference.	Area.	Diameter.	Circumference.	Area.
$\frac{1}{16}$	·1963	·00307	$2\frac{9}{16}$	8·0503	5·1573
$\frac{1}{8}$	·3927	·01227	$2\frac{5}{8}$	8·2467	5·4119
$\frac{3}{16}$	·5890	·02761	$2\frac{11}{16}$	8·4430	5·6723
$\frac{1}{4}$	·7854	·04909	$2\frac{3}{4}$	8·6394	5·9395
$\frac{5}{16}$	·9817	·07670	$2\frac{13}{16}$	8·8357	6·2126
$\frac{3}{8}$	1·1781	·1104	$2\frac{7}{8}$	9·0321	6·4918
$\frac{7}{16}$	1·3744	·1503	$2\frac{15}{16}$	9·2284	6·7772
$\frac{1}{2}$	1·5708	·1963	3	9·4248	7·0686
$\frac{9}{16}$	1·7771	·2485	$3\frac{1}{16}$	9·6211	7·3662
$\frac{5}{8}$	1·9635	·3068	$3\frac{1}{8}$	9·8175	7·6699
$\frac{11}{16}$	2·1598	·3712	$3\frac{3}{16}$	10·014	7·9798
$\frac{3}{4}$	2·3562	·4417	$3\frac{1}{4}$	10·210	8·2957
$\frac{13}{16}$	2·5525	·5185	$3\frac{5}{16}$	10·406	8·6180
$\frac{7}{8}$	2·7489	·6013	$3\frac{3}{8}$	10·602	8·9462
$\frac{15}{16}$	2·9452	·6903	$3\frac{7}{16}$	10·799	9·2807
1	3·1416	·7854	$3\frac{1}{2}$	10·995	9·6211
$1\frac{1}{16}$	3·3379	·8866	$3\frac{9}{16}$	11·191	9·9680
$1\frac{1}{8}$	3·5343	·9940	$3\frac{5}{8}$	11·388	10·320
$1\frac{3}{16}$	3·7306	1·1075	$3\frac{11}{16}$	11·584	10·679
$1\frac{1}{4}$	3·9270	1·2271	$3\frac{3}{4}$	11·781	11·044
$1\frac{5}{16}$	4·1233	1·3530	$3\frac{13}{16}$	11·977	11·416
$1\frac{3}{8}$	4·3197	1·4848	$3\frac{7}{8}$	12·173	11·793
$1\frac{7}{16}$	4·5160	1·6229	$3\frac{15}{16}$	12·369	12·177
$1\frac{1}{2}$	4·7124	1·7671	4	12·566	12·566
$1\frac{9}{16}$	4·9087	1·9175	$4\frac{1}{16}$	12·762	12·962
$1\frac{5}{8}$	5·1051	2·0739	$4\frac{1}{8}$	12·959	13·364
$1\frac{11}{16}$	5·3014	2·2365	$4\frac{3}{16}$	13·155	13·772
$1\frac{3}{4}$	5·4978	2·4052	$4\frac{1}{4}$	13·351	14·186
$1\frac{13}{16}$	5·6941	2·5800	$4\frac{5}{16}$	13·547	14·606
$1\frac{7}{8}$	5·8905	2·7611	$4\frac{3}{8}$	13·744	15·033
$1\frac{15}{16}$	6·0868	2·9483	$4\frac{7}{16}$	13·940	15·465
2	6·2832	3·1416	$4\frac{1}{2}$	14·137	15·904
$2\frac{1}{16}$	6·4795	3·3380	$4\frac{9}{16}$	14·333	16·349
$2\frac{1}{8}$	6·6759	3·5465	$4\frac{5}{8}$	14·529	16·800
$2\frac{3}{16}$	6·8722	3·7584	$4\frac{11}{16}$	14·725	17·257
$2\frac{1}{4}$	7·0686	3·9760	$4\frac{3}{4}$	14·922	17·720
$2\frac{5}{16}$	7·2649	4·2000	$4\frac{13}{16}$	15·119	18·190
$2\frac{3}{8}$	7·4613	4·4302	$4\frac{7}{8}$	15·315	18·665
$2\frac{7}{16}$	7·6576	4·7066	$4\frac{15}{16}$	15·511	19·147
$2\frac{1}{2}$	7·8540	4·9087	5	15·708	19·635

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Diameter.	Circumference.	Area.	Diameter.	Circumference.	Area.
$5\frac{1}{16}$	15·904	20·129	$9\frac{3}{8}$	29·452	69·029
$5\frac{1}{8}$	16·100	20·629	$9\frac{1}{2}$	29·845	70·882
$5\frac{3}{16}$	16·296	21·135	$9\frac{5}{8}$	30·237	72·759
$5\frac{1}{4}$	16·493	21·647	$9\frac{3}{4}$	30·630	74·662
$5\frac{5}{16}$	16·689	22·166	$9\frac{7}{8}$	31·023	76·588
$5\frac{3}{8}$	16·886	22·690	10	31·416	78·540
$5\frac{7}{16}$	17·082	23·221	$10\frac{1}{8}$	31·808	80·515
$5\frac{1}{2}$	17·278	23·758	$10\frac{1}{4}$	32·201	82·516
$5\frac{9}{16}$	17·474	24·301	$10\frac{3}{8}$	32·594	84·540
$5\frac{5}{8}$	17·671	24·850	$10\frac{1}{2}$	32·986	86·590
$5\frac{11}{16}$	17·867	25·406	$10\frac{5}{8}$	33·379	88·664
$5\frac{3}{4}$	18·064	25·967	$10\frac{3}{4}$	33·772	90·762
$5\frac{13}{16}$	18·261	26·535	$10\frac{7}{8}$	34·164	92·885
$5\frac{7}{8}$	18·457	27·108	11	34·558	95·033
$5\frac{15}{16}$	18·653	27·688	$11\frac{1}{8}$	34·950	97·205
6	18·849	28·274	$11\frac{1}{4}$	35·343	99·402
$6\frac{1}{8}$	19·242	29·464	$11\frac{3}{8}$	35·735	101·623
$6\frac{1}{4}$	19·635	30·679	$11\frac{1}{2}$	36·128	103·869
$6\frac{3}{8}$	20·027	31·919	$11\frac{5}{8}$	36·521	106·139
$6\frac{1}{2}$	20·420	33·183	$11\frac{3}{4}$	36·913	108·434
$6\frac{5}{8}$	20·813	34·471	$11\frac{7}{8}$	37·306	110·753
$6\frac{3}{4}$	21·205	35·784	12	37·699	113·097
$6\frac{7}{8}$	21·598	37·122	$12\frac{1}{8}$	38·091	115·466
7	21·991	38·484	$12\frac{1}{4}$	38·484	117·859
$7\frac{1}{8}$	22·383	39·871	$12\frac{3}{8}$	38·877	120·276
$7\frac{1}{4}$	22·776	41·282	$12\frac{1}{2}$	39·270	122·718
$7\frac{3}{8}$	23·169	42·718	$12\frac{5}{8}$	39·662	125·184
$7\frac{1}{2}$	23·562	44·178	$12\frac{3}{4}$	40·055	127·676
$7\frac{5}{8}$	23·954	45·663	$12\frac{7}{8}$	40·448	130·192
$7\frac{3}{4}$	24·347	47·173	13	40·840	132·732
$7\frac{7}{8}$	24·740	48·707	$13\frac{1}{8}$	41·233	135·297
8	25·132	50·265	$13\frac{1}{4}$	41·626	137·886
$8\frac{1}{8}$	25·515	51·848	$13\frac{3}{8}$	42·018	140·500
$8\frac{1}{4}$	25·918	53·456	$13\frac{1}{2}$	42·411	143·139
$8\frac{3}{8}$	26·310	55·088	$13\frac{5}{8}$	42·804	145·802
$8\frac{1}{2}$	26·703	56·745	$13\frac{3}{4}$	43·197	148·489
$8\frac{5}{8}$	27·096	58·426	$13\frac{7}{8}$	43·589	151·201
$8\frac{3}{4}$	27·489	60·132	14	43·982	153·938
$8\frac{7}{8}$	27·881	61·862	$14\frac{1}{8}$	44·375	156·699
9	28·274	63·617	$14\frac{1}{4}$	44·767	159·485
$9\frac{1}{8}$	28·667	65·396	$14\frac{3}{8}$	45·160	162·295
$9\frac{1}{4}$	29·059	67·200	$14\frac{1}{2}$	45·553	165·130

Diameter.	Circumference.	Area.	Diameter.	Circumference.	Area.
14⅝	45·945	167·989	**19⅞**	62·439	310·245
14¾	46·338	170·873	**20**	62·832	314·160
14⅞	46·731	173·782	**20⅛**	63·224	318·099
15	47·124	176·715	**20¼**	63·617	322·063
15⅛	47·516	179·672	**20⅜**	64·010	326·051
15¼	47·909	182·654	**20½**	64·402	330·064
15⅜	48·302	185·661	**20⅝**	64·795	334·101
15½	48·694	188·692	**20¾**	65·188	338·163
15⅝	49·087	191·748	**20⅞**	65·580	342·250
15¾	49·480	194·828	**21**	65·973	346·361
15⅞	49·872	197·933	**21⅛**	66·366	350·497
16	50·265	201·062	**21¼**	66·759	354·657
16⅛	50·658	204·216	**21⅜**	67·151	358·841
16¼	51·051	207·394	**21½**	67·544	363·051
16⅜	51·443	210·597	**21⅝**	67·937	367·284
16½	51·836	213·825	**21¾**	68·329	371·543
16⅝	52·229	217·077	**21⅞**	68·722	375·826
16¾	52·621	220·353	**22**	69·115	380·133
16⅞	53·014	223·654	**22⅛**	69·507	384·465
17	53·407	226·980	**22¼**	69·900	388·822
17⅛	53·799	230·330	**22⅜**	70·293	393·203
17¼	54·192	233·705	**22½**	70·686	397·608
17⅜	54·585	237·104	**22⅝**	71·078	402·038
17½	54·978	240·528	**22¾**	71·471	406·493
17⅝	55·370	243·977	**22⅞**	71·864	410·972
17¾	55·763	247·450	**23**	72·256	415·476
17⅞	56·156	250·947	**23⅛**	72·649	420·004
18	56·548	254·469	**23¼**	73·042	424·557
18⅛	56·941	258·016	**23⅜**	73·434	429·135
18¼	57·334	261·587	**23½**	73·827	433·731
18⅜	57·726	265·182	**23⅝**	74·220	438·363
18½	58·119	268·803	**23¾**	74·613	443·014
18⅝	58·512	272·447	**23⅞**	75·005	447·699
18¾	58·905	276·117	**24**	75·398	452·390
18⅞	59·297	279·811	**24⅛**	75·791	457·115
19	59·690	283·529	**24¼**	76·183	461·864
19⅛	60·083	287·272	**24⅜**	76·576	466·638
19¼	60·475	291·039	**24½**	76·969	471·436
19⅜	60·868	294·831	**24⅝**	77·361	476·259
19½	61·261	298·648	**24¾**	77·754	481·106
19⅝	61·653	302·489	**24⅞**	78·147	485·978
19¾	62·046	306·355	**25**	78·540	490·875

Diameter.	Circumference.	Area.	Diameter.	Circumference.	Area.
25⅛	78·932	495·796	**30⅜**	95·426	724·641
25¼	79·325	500·741	**30½**	95·818	730·618
25⅜	79·718	505·711	**30⅝**	96·211	736·619
25½	80·110	510·706	**30¾**	96·604	742·644
25⅝	80·503	515·725	**30⅞**	96·996	748·694
25¾	80·896	520·769	**31**	97·389	754·769
25⅞	81·288	525·837	**31⅛**	97·782	760·868
26	81·681	530·930	**31¼**	98·175	766·992
26⅛	82·074	536·047	**31⅜**	98·567	773·140
26¼	82·467	541·189	**31½**	98·968	779·313
26⅜	82·859	546·356	**31⅝**	99·353	785·510
26½	83·252	551·547	**31¾**	99·745	791·732
26⅝	83·645	556·762	**31⅞**	100·138	797·978
26¾	84·037	562·002	**32**	100·531	804·249
26⅞	84·430	567·267	**32⅛**	100·924	810·545
27	84·823	572·556	**32¼**	101·316	816·865
27⅛	85·215	577·870	**32⅜**	101·709	823·209
27¼	85·608	583·208	**32½**	102·102	829·578
27⅜	86·001	588·571	**32⅝**	102·494	835·972
27½	86·394	593·958	**32¾**	102·887	842·390
27⅝	86·786	599·370	**32⅞**	103·280	848·833
27¾	87·179	604·807	**33**	103·672	855·30
27⅞	87·572	610·268	**33⅛**	104·055	861·79
28	87·964	615·753	**33¼**	104·458	868·30
28⅛	88·357	621·263	**33⅜**	104·850	874·84
28¼	88·750	626·798	**33½**	105·243	881·41
28⅜	89·142	632·357	**33⅝**	105·636	888·00
28½	89·535	637·941	**33¾**	106·029	894·61
28⅝	89·928	643·594	**33⅞**	106·421	901·25
28¾	90·321	649·182	**34**	106·814	907·92
28⅞	90·713	654·839	**34⅛**	107·207	914·61
29	91·106	660·521	**34¼**	107·599	921·32
29⅛	91·499	666·227	**34⅜**	107·992	928·06
29¼	91·891	671·958	**34½**	108·385	934·82
29⅜	92·284	677·714	**34⅝**	108·777	941·60
29½	92·677	683·494	**34¾**	109·170	948·41
29⅝	93·069	689·298	**34⅞**	109·563	955·25
29¾	93·462	695·128	**35**	109·956	962·11
29⅞	93·855	700·981	**35⅛**	110·348	968·99
30	94·248	706·860	**35¼**	110·741	975·90
30⅛	94·640	712·762	**35⅜**	111·134	982·84
30¼	95·033	718·690	**35½**	111·526	989·80

Diameter.	Circumference.	Area.	Diameter.	Circumference.	Area.
63¼	198·706	3142·04	**73¾**	231·693	4271·83
63½	199·491	3166·92	**74**	232·478	4300·84
63¾	200·277	3191·91	**74¼**	233·263	4329·95
64	201·062	3216·99	**74½**	234·049	4359·16
64¼	201·847	3242·17	**74¾**	234·834	4388·47
64½	202·633	3267·46	**75**	235·620	4417·86
64¾	203·418	3292·83	**75¼**	236·405	4447·37
65	204·204	3318·31	**75½**	237·190	4476·97
65¼	204·989	3343·88	**75¾**	237·976	4506·67
65½	205·774	3369·56	**76**	238·761	4536·46
65¾	206·560	3395·33	**76¼**	239·547	4566·36
66	207·345	3421·19	**76½**	240·332	4596·35
66¼	208·131	3447·16	**76¾**	241·117	4626·44
66½	208·916	3473·23	**77**	241·903	4656·63
66¾	209·701	3499·39	**77¼**	242·688	4686·92
67	210·487	3525·66	**77½**	243·474	4717·30
67¼	211·272	3552·01	**77¾**	244·259	4747·79
67½	212·058	3578·47	**78**	245·044	4778·36
67¾	212·843	3605·03	**78¼**	245·830	4809·05
68	213·628	3631·68	**78½**	246·615	4839·83
68¼	214·414	3658·44	**78¾**	247·401	4870·70
68½	215·199	3685·29	**79**	248·186	4901·68
68¾	215·985	3712·24	**79¼**	248·971	4932·75
69	216·770	3739·28	**79½**	249·757	4963·92
69¼	217·555	3766·43	**79¾**	250·542	4995·19
69½	218·341	3793·67	**80**	251·328	5026·55
69¾	219·126	3821·02	**80¼**	252·113	5058·00
70	219·912	3848·45	**80½**	252·898	5089·58
70¼	220·697	3875·99	**80¾**	253·683	5121·22
70½	221·482	3903·63	**81**	254·469	5153·00
70¾	222·268	3931·36	**81¼**	255·254	5184·84
71	223·053	3959·19	**81½**	256·040	5216·82
71¼	223·839	3987·13	**81¾**	256·825	5248·84
71½	224·624	4015·16	**82**	257·611	5281·02
71¾	225·409	4043·28	**82¼**	258·396	5313·28
72	226·195	4071·50	**82½**	259·182	5345·62
72¼	226·980	4099·83	**82¾**	259·967	5378·04
72½	227·766	4128·25	**83**	260·752	5410·61
72¾	228·551	4156·77	**83¼**	261·537	5443·24
73	229·336	4185·39	**83½**	262·323	5476·00
73¼	230·122	4214·11	**83¾**	263·108	5508·84
73½	230·907	4242·92	**84**	263·894	5541·77

Diameter.	Circumference.	Area.	Diameter.	Circumference.	Area.
84¼	264·679	5574·80	**94¾**	297·666	7050·92
84½	265·465	5607·95	**95**	298·452	7088·22
84¾	266·250	5641·16	**95¼**	299·237	7125·56
85	267·035	5674·51	**95½**	300·022	7163·04
85¼	267·821	5707·92	**95¾**	300·807	7200·56
85½	268·606	5741·47	**96**	301·593	7238·23
85¾	269·392	5775·09	**96¼**	302·378	7275·96
86	270·177	5808·80	**96½**	302·164	7313·84
86¼	270·962	5842·60	**96¾**	303·948	7351·72
86½	271·748	5876·55	**97**	304·734	7389·81
86¾	272·533	5910·52	**97¼**	305·520	7427·96
87	273·319	5944·68	**97½**	306·306	7474·20
87¼	274·104	5978·88	**97¾**	307·090	7504·52
87½	274·890	6013·21	**98**	307·876	7542·96
87¾	275·675	6047·60	**98¼**	308·662	7581·48
88	276·460	6082·12	**98½**	309·446	7620·12
88¼	277·245	6116·72	**98¾**	310·232	7658·80
88½	278·031	6151·44	**99**	311·018	7697·69
88¾	278·816	6186·20	**99¼**	311·802	7736·60
89	279·602	6221·14	**99½**	312·588	7775·64
89¼	280·387	6256·12	**99¾**	313·374	7814·76
89½	281·173	6291·25	**100**	314·159	7853·98
89¾	281·958	6326·44	**100½**	315·730	7938·72
90	282·744	6361·73	**101**	317·301	8011·85
90¼	283·529	6399·12	**101½**	318·872	8091·36
90½	284·314	6432·62	**102**	320·442	8171·28
90¾	285·099	6468·16	**102½**	322·014	8251·60
91	285·885	6503·88	**103**	323·584	8332·29
91¼	286·670	6539·68	**103½**	325·154	8413·40
91½	287·456	6573·56	**104**	326·726	8494·87
91¾	288·242	6611·52	**104½**	328·296	8576·76
92	289·027	6647·61	**105**	329·867	8659·01
92¼	289·812	6683·80	**105½**	331·438	8741·68
92½	290·598	6720·07	**106**	333·009	8824·73
92¾	291·383	6756·40	**106½**	334·580	8908·20
93	292·168	6792·91	**107**	336·150	8992·02
93¼	292·953	6829·48	**107½**	337·722	9076·24
93½	293·739	6866·16	**108**	339·292	9160·88
93¾	294·524	6882·92	**108½**	340·862	9245·92
94	295·310	6939·78	**109**	342·434	9331·32
94¼	296·095	6976·72	**109½**	344·004	9417·12
94½	296·881	7013·81	**110**	345·575	9503·32

Diameter.	Circumference.	Area.	Diameter.	Circumference.	Area.
110½	347·146	9589·92	**115½**	362·854	10477·40
111	348·717	9676·89	**116**	364·425	10568·32
111½	350·288	9764·28	**116½**	365·996	10659·64
112	351·858	9852·03	**117**	367·566	10751·32
112½	353·430	9940·20	**117½**	369·138	10843·40
113	355·000	10028·75	**118**	370·708	10935·88
113½	356·570	10117·68	**118½**	372·278	11028·76
114	358·142	10207·03	**119**	373·849	11122·02
114½	359·712	10296·76	**119½**	375·420	11215·68
115	361·283	10386·89	**120**	376·991	11309·73

TABLE 3.—RECIPROCALS OF NUMBERS, FROM 1 TO 1,000.*

No.	Reciprocal.	No.	Reciprocal.	No.	Reciprocal.	No.	Reciprocal.
1	1·000000	**25**	·040000	**49**	·020408	**73**	·013699
2	·500000	**26**	·038462	**50**	·020000	**74**	·013514
3	·333333	**27**	·037037	**51**	·019608	**75**	·013333
4	·250000	**28**	·035714	**52**	·019231	**76**	·013158
5	·200000	**29**	·034483	**53**	·018868	**77**	·012987
6	·166667	**30**	·033333	**54**	·018519	**78**	·012821
7	·142857	**31**	·032258	**55**	·018182	**79**	·012658
8	·125000	**32**	·031250	**56**	·017857	**80**	·012500
9	·111111	**33**	·030303	**57**	·017544	**81**	·012346
10	·100000	**34**	·029412	**58**	·017241	**82**	·012195
11	·090909	**35**	·028571	**59**	·016949	**83**	·012048
12	·083333	**36**	·027778	**60**	·016667	**84**	·011905
13	·076923	**37**	·027027	**61**	·016393	**85**	·011765
14	·071429	**38**	·026316	**62**	·016129	**86**	·011628
15	·066667	**39**	·025641	**63**	·015873	**87**	·011494
16	·062500	**40**	·025000	**64**	·015625	**88**	·011364
17	·058824	**41**	·024390	**65**	·015385	**89**	·011236
18	·055556	**42**	·023810	**66**	·015152	**90**	·011111
19	·052632	**43**	·023256	**67**	·014925	**91**	·010989
20	·050000	**44**	·022727	**68**	·014706	**92**	·010870
21	·047619	**45**	·022222	**69**	·014493	**93**	·010753
22	·045455	**46**	·021739	**70**	·014286	**94**	·010638
23	·043478	**47**	·021277	**71**	·014085	**95**	·010526
24	·041667	**48**	·020833	**72**	·013889	**96**	·010417

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* See Introduction, *ante*, p. 2.

No.	Reci-procal.	No.	Reci-procal.	No.	Reci-procal.	No.	Reci-procal.
97	·010309	**139**	·007194	**181**	·005525	**223**	·004484
98	·010204	**140**	·007143	**182**	·005495	**224**	·004464
99	·010101	**141**	·007092	**183**	·005464	**225**	·004444
100	·010000	**142**	·007042	**184**	·005435	**226**	·004425
101	·009901	**143**	·006993	**185**	·005405	**227**	·004405
102	·009804	**144**	·006944	**186**	·005376	**228**	·004386
103	·009709	**145**	·006897	**187**	·005348	**229**	·004367
104	·009615	**146**	·006849	**188**	·005319	**230**	·004348
105	·009524	**147**	·006803	**189**	·005291	**231**	·004329
106	·009434	**148**	·006757	**190**	·005263	**232**	·004310
107	·009346	**149**	·006711	**191**	·005236	**233**	·004292
108	·009259	**150**	·006667	**192**	·005208	**234**	·004274
109	·009174	**151**	·006623	**193**	·005181	**235**	·004255
110	·009091	**152**	·006579	**194**	·005155	**236**	·004237
111	·009009	**153**	·006536	**195**	·005128	**237**	·004219
112	·008929	**154**	·006494	**196**	·005102	**238**	·004202
113	·008850	**155**	·006452	**197**	·005076	**239**	·004184
114	·008772	**156**	·006410	**198**	·005051	**240**	·004167
115	·008696	**157**	·006369	**199**	·005025	**241**	·004149
116	·008621	**158**	·006329	**200**	·005000	**242**	·004132
117	·008547	**159**	·006289	**201**	·004975	**243**	·004115
118	·008475	**160**	·006250	**202**	·004950	**244**	·004098
119	·008403	**161**	·006211	**203**	·004926	**245**	·004082
120	·008333	**162**	·006173	**204**	·004902	**246**	·004065
121	·008264	**163**	·006135	**205**	·004878	**247**	·004049
122	·008197	**164**	·006098	**206**	·004854	**248**	·004032
123	·008130	**165**	·006061	**207**	·004831	**249**	·004016
124	·008065	**166**	·006024	**208**	·004808	**250**	·004000
125	·008000	**167**	·005988	**209**	·004785	**251**	·003984
126	·007937	**168**	·005952	**210**	·004762	**252**	·003968
127	·007874	**169**	·005917	**211**	·004739	**253**	·003953
128	·007813	**170**	·005882	**212**	·004717	**254**	·003937
129	·007752	**171**	·005848	**213**	·004695	**255**	·003922
130	·007692	**172**	·005814	**214**	·004673	**256**	·003906
131	·007634	**173**	·005780	**215**	·004651	**257**	·003891
132	·007576	**174**	·005747	**216**	·004630	**258**	·003876
133	·007519	**175**	·005714	**217**	·004608	**259**	·003861
134	·007463	**176**	·005682	**218**	·004587	**260**	·003846
135	·007407	**177**	·005650	**219**	·004566	**261**	·003831
136	·007353	**178**	·005618	**220**	·004545	**262**	·003817
137	·007299	**179**	·005587	**221**	·004525	**263**	·003802
138	·007246	**180**	·005556	**222**	·004505	**264**	·003788

No.	Reciprocal.	No.	Reciprocal.	No.	Reciprocal.	No.	Reciprocal.
265	·003774	**307**	·003257	**349**	·002865	**391**	·002558
266	·003759	**308**	·003247	**350**	·002857	**392**	·002551
267	·003745	**309**	·003236	**351**	·002849	**393**	·002545
268	·003731	**310**	·003226	**352**	·002841	**394**	·002538
269	·003717	**311**	·003215	**353**	·002833	**395**	·002532
270	·003704	**312**	·003205	**354**	·002825	**396**	·002525
271	·003690	**313**	·003195	**355**	·002817	**397**	·002519
272	·003676	**314**	·003185	**356**	·002809	**398**	·002513
273	·003663	**315**	·003175	**357**	·002801	**399**	·002506
274	·003650	**316**	·003165	**358**	·002793	**400**	·002500
275	·003636	**317**	·003155	**359**	·002786	**401**	·002494
276	·003623	**318**	·003145	**360**	·002778	**402**	·002488
277	·003610	**319**	·003135	**361**	·002770	**403**	·002481
278	·003597	**320**	·003125	**362**	·002762	**404**	·002475
279	·003584	**321**	·003115	**363**	·002755	**405**	·002469
280	·003571	**322**	·003106	**364**	·002747	**406**	·002463
281	·003559	**323**	·003096	**365**	·002740	**407**	·002457
282	·003546	**324**	·003086	**366**	·002732	**408**	·002451
283	·003534	**325**	·003077	**367**	·002725	**409**	·002445
284	·003522	**326**	·003067	**368**	·002717	**410**	·002439
285	·003509	**327**	·003058	**369**	·002710	**411**	·002433
286	·003497	**328**	·003049	**370**	·002703	**412**	·002427
287	·003484	**329**	·003040	**371**	·002695	**413**	·002421
288	·003472	**330**	·003030	**372**	·002688	**414**	·002415
289	·003460	**331**	·003021	**373**	·002681	**415**	·002410
290	·003448	**332**	·003012	**374**	·002674	**416**	·002407
291	·003436	**333**	·003003	**375**	·002667	**417**	·002398
292	·003425	**334**	·002994	**376**	·002660	**418**	·002392
293	·003413	**335**	·002985	**377**	·002653	**419**	·002387
294	·003401	**336**	·002976	**378**	·002646	**420**	·002381
295	·003390	**337**	·002967	**379**	·002639	**421**	·002375
296	·003378	**338**	·002959	**380**	·002632	**422**	·002370
297	·003367	**339**	·002950	**381**	·002625	**423**	·002364
298	·003356	**340**	·002941	**382**	·002618	**424**	·002358
299	·003344	**341**	·002933	**383**	·002611	**425**	·002353
300	·003333	**342**	·002924	**384**	·002604	**426**	·002347
301	·003322	**343**	·002915	**385**	·002597	**427**	·002342
302	·003311	**344**	·002907	**386**	·002591	**428**	·002336
303	·003301	**345**	·002899	**387**	·002584	**429**	·002331
304	·003289	**346**	·002890	**388**	·002577	**430**	·002326
305	·003279	**347**	·002882	**389**	·002571	**431**	·002320
306	·003268	**348**	·002874	**390**	·002564	**432**	·002315

No.	Reciprocal.	No.	Reciprocal.	No.	Reciprocal.	No.	Reciprocal.
433	·002309	475	·002105	517	·001934	559	·001789
434	·002304	476	·002101	518	·001931	560	·001786
435	·002299	477	·002096	519	·001927	561	·001783
436	·002294	478	·002092	520	·001923	562	·001779
437	·002288	479	·002088	521	·001919	563	·001776
438	·002283	480	·002083	522	·001916	564	·001773
439	·002278	481	·002079	523	·001912	565	·001770
440	·002273	482	·002075	524	·001908	566	·001767
441	·002268	483	·002070	525	·001905	567	·001764
442	·002262	484	·002066	526	·001901	568	·001761
443	·002257	485	·002062	527	·001898	569	·001757
444	·002252	486	·002058	528	·001894	570	·001754
445	·002247	487	·002053	529	·001890	571	·001751
446	·002242	488	·002049	530	·001887	572	·001748
447	·002237	489	·002045	531	·001883	573	·001745
448	·002232	490	·002041	532	·001880	574	·001742
449	·002227	491	002037	533	·001876	575	·001739
450	·002222	492	·002033	534	·001873	576	·001736
451	·002217	493	·002028	535	·001869	577	·001733
452	·002212	494	·002024	536	·001866	578	·001730
453	·002208	495	·002020	537	·001862	579	·001727
454	·002203	496	·002016	538	·001859	580	·001724
455	·002198	497	·002012	539	·001855	581	·001721
456	·002193	498	·002008	540	·001852	582	·001718
457	·002188	499	·002004	541	·001848	583	·001715
458	·002183	500	·002000	542	·001845	584	·001712
459	·002179	501	·001996	543	·001842	585	·001709
460	·002174	502	·001992	544	·001838	586	·001706
461	·002169	503	·001988	545	·001835	587	·001704
462	·002165	504	·001984	546	·001832	588	·001701
463	·002160	505	·001980	547	·001828	589	·001698
464	·002155	506	·001976	548	·001825	590	·001695
465	·002151	507	·001972	549	·001821	591	·001692
466	·002146	508	·001969	550	·001818	592	·001689
467	·002141	509	·001965	551	·001815	593	·001686
468	·002137	510	·001961	552	·001812	594	·001684
469	·002132	511	·001957	553	·001808	595	·001681
470	·002128	512	·001953	554	·001805	596	·001678
471	·002123	513	·001949	555	·001802	597	·001675
472	·002119	514	·001946	556	·001799	598	·001672
473	·002114	515	·001942	557	·001795	599	·001669
474	·002110	516	·001938	558	·001792	600	·001667

No.	Reciprocal.	No.	Reciprocal.	No.	Reciprocal.	No.	Reciprocal.
601	·001664	**643**	·001555	**685**	·001460	**727**	·001376
602	·001661	**644**	·001553	**686**	·001458	**728**	·001374
603	·001658	**645**	·001550	**687**	·001456	**729**	·001372
604	·001656	**646**	·001548	**688**	·001453	**730**	·001370
605	·001653	**647**	·001546	**689**	·001451	**731**	·001368
606	·001650	**648**	·001543	**690**	·001449	**732**	·001366
607	·001647	**649**	·001541	**691**	·001447	**733**	·001364
608	·001645	**650**	·001538	**692**	·001445	**734**	·001362
609	·001642	**651**	·001536	**693**	·001443	**735**	·001361
610	·001639	**652**	·001534	**694**	·001441	**736**	·001359
611	·001637	**653**	·001531	**695**	·001439	**737**	·001357
612	·001634	**654**	·001529	**696**	·001437	**738**	·001355
613	·001631	**655**	·001527	**697**	·001435	**739**	·001353
614	·001629	**656**	·001524	**698**	·001433	**740**	·001351
615	·001626	**657**	·001522	**699**	·001431	**741**	·001350
616	·001623	**658**	·001520	**700**	·001429	**742**	·001348
617	·001621	**659**	·001517	**701**	·001427	**743**	·001346
618	·001618	**660**	·001515	**702**	·001425	**744**	·001344
619	·001616	**661**	·001513	**703**	·001422	**745**	·001342
620	·001613	**662**	·001511	**704**	·001420	**746**	·001340
621	·001610	**663**	·001508	**705**	·001418	**747**	·001339
622	·001608	**664**	·001506	**706**	·001416	**748**	·001337
623	·001605	**665**	·001504	**707**	·001414	**749**	·001335
624	·001603	**666**	·001502	**708**	·001412	**750**	·001333
625	·001600	**667**	·001499	**709**	·001410	**751**	·001332
626	·001597	**668**	·001497	**710**	·001408	**752**	·001330
627	·001595	**669**	·001495	**711**	·001406	**753**	·001328
628	·001592	**670**	·001493	**712**	·001404	**754**	·001326
629	·001590	**671**	·001490	**713**	·001403	**755**	·001325
630	·001587	**672**	·001488	**714**	·001401	**756**	·001323
631	·001585	**673**	·001486	**715**	·001399	**757**	·001321
632	·001582	**674**	·001484	**716**	·001397	**758**	·001319
633	·001580	**675**	·001481	**717**	·001395	**759**	·001318
634	·001577	**676**	·001479	**718**	·001393	**760**	·001316
635	·001575	**677**	·001477	**719**	·001391	**761**	·001314
636	·001572	**678**	·001475	**720**	·001389	**762**	·001312
637	·001570	**679**	·001473	**721**	·001387	**763**	·001311
638	·001567	**680**	·001471	**722**	·001385	**764**	·001309
639	·001565	**681**	·001468	**723**	·001383	**765**	·001307
640	·001563	**682**	·001466	**724**	·001381	**766**	·001305
641	·001560	**683**	·001464	**725**	·001379	**767**	·001304
642	·001558	**684**	·001462	**726**	·001377	**768**	·001302

No	Reci-procal.	No.	Reci-procal.	No.	Reci-procal.	No.	Reci-procal.
769	·001300	811	·001233	853	·001172	895	·001118
770	·001299	812	·001232	854	·001171	896	·001116
771	·001297	813	·001230	855	·001170	897	·001115
772	·001295	814	·001229	856	·001168	898	·001114
773	·001294	815	·001227	857	·001167	899	·001112
774	·001292	816	·001225	858	·001166	900	·001111
775	·001290	817	·001224	859	·001164	901	·001110
776	·001289	818	·001222	860	·001163	902	·001109
777	·001287	819	·001221	861	·001161	903	·001107
778	·001285	820	·001220	862	·001160	904	·001106
779	·001284	821	·001218	863	·001159	905	·001105
780	·001282	822	·001217	864	·001157	906	·001104
781	·001280	823	·001215	865	·001156	907	·001103
782	·001279	824	·001214	866	·001155	908	·001101
783	·001277	825	·001212	867	·001153	909	·001100
784	·001276	826	·001211	868	·001152	910	·001099
785	·001274	827	·001209	869	·001151	911	·001098
786	·001272	828	·001208	870	·001149	912	·001096
787	·001271	829	·001206	871	·001148	913	·001095
788	·001269	830	·001205	872	·001147	914	·001094
789	·001267	831	·001203	873	·001145	915	·001093
790	·001266	832	·001202	874	·001144	916	·001092
791	·001264	833	·001200	875	·001143	917	·001091
792	·001263	834	·001199	876	·001142	918	·001089
793	·001261	835	·001198	877	·001140	919	·001088
794	·001259	836	·001196	878	·001139	920	·001087
795	·001258	837	·001195	879	·001138	921	·001086
796	·001256	838	·001193	880	·001136	922	·001085
797	·001255	839	·001192	881	·001135	923	·001083
798	·001253	840	·001190	882	·001134	924	·001082
799	·001251	841	·001189	883	·001133	925	·001081
800	·001250	842	·001188	884	·001131	926	·001080
801	·001248	843	·001186	885	·001130	927	·001079
802	·001247	844	·001185	886	·001129	928	·001078
803	·001245	845	·001183	887	·001127	929	·001076
804	·001244	846	·091182	888	·001126	930	·001075
805	·001242	847	·001181	889	·001125	931	·001074
806	·001241	848	·001179	890	·001124	932	·001073
807	·001239	849	·001178	891	·001122	933	·001072
808	·001238	850	·001176	892	·001121	934	·001071
809	·001236	851	·001175	893	·001120	935	·001070
810	·001235	852	·001174	894	·001119	936	·001068

No.	Reciprocal.	No.	Reciprocal.	No.	Reciprocal.	No.	Reciprocal.
937	·001067	**953**	·001049	**969**	·001032	**985**	·001015
938	·001066	**954**	·001048	**970**	·001031	**986**	·001014
939	·001065	**955**	·001047	**971**	·001030	**987**	·001013
940	·001064	**956**	·001046	**972**	·001029	**988**	·001012
941	·001063	**957**	·001045	**973**	·001028	**989**	·001011
942	·001062	**958**	·001044	**974**	·001027	**990**	·001010
943	·001060	**959**	·001043	**975**	·001026	**991**	·001009
944	·001059	**960**	·001042	**976**	·001025	**992**	·001008
945	·001058	**961**	·001041	**977**	·001024	**993**	·001007
946	·001057	**962**	·001040	**978**	·001022	**994**	·001006
947	·001056	**963**	·001038	**979**	·001021	**995**	·001005
948	·001055	**964**	·001037	**980**	·001020	**996**	·001004
949	·001054	**965**	·001036	**981**	·001019	**997**	·001003
950	·001053	**966**	·001035	**982**	·001018	**998**	·001002
951	·001052	**967**	·001034	**983**	·001017	**999**	·001001
952	·001050	**968**	·001033	**984**	·001016	**1000**	·001000

TABLE 3A.—RHUMBS, OR POINTS OF THE COMPASS.

Points.	Angles.	NORTH.	NORTH.	SOUTH.	SOUTH.
¼	2° 48′ 45″	N ¼ E	N ¼ W	S ¼ E	S ¼ W
½	5 37 30	N ½ E	N ½ W	S ½ E	S ½ W
¾	8 26 15	N ¾ E	N ¾ W	S ¾ E	S ¾ W
1	11 15 0	N by E	N by W	S by E	S by W
1½	16 52 30	N by E ½ E	N by W ½ W	S by E ½ E	S by W ½ W
2	22 30 0	NNE	NNW	SSE	SSW
2½	28 7 30	NNE ½ E	NNW ½ W	SSE ½ E	SSW ½ W
3	33 45 0	NE by N	NW by N	SE by S	SW by S
3½	39 22 30	NE ½ N	NW ½ N	SE ½ S	SW ½ S
4	45 0 0	NE	NW	SE	SW
4½	50 37 30	NE ½ E	NW ½ W	SE ½ E	SW ½ W
5	56 15 0	NE by E	NW by W	SE by E	SW by W
5½	61 52 30	ENE ½ N	WNW ½ N	ESE ½ S	WSW ½ S
6	67 30 0	ENE	WNW	ESE	WSW
6½	73 7 30	ENE ½ E	WNW ½ W	ESE ½ E	WSW ½ W
7	78 45 0	E by N	W by N	E by S	W by S
7½	84 22 30	E ½ N	W ½ N	E ½ S	W ½ S
8	90 0 0	EAST	WEST	EAST	WEST

TABLE 4.—LOGARITHMS OF NUMBERS, FROM 1 TO 10,000.*

N.	0	1	2	3	4	5	6	7	8	9	N.
0	—	000000	301030	477121	602060	698970	778151	845098	903090	954243	**0**
1	000000	041393	079181	113943	146128	176091	204120	230449	255273	278754	**1**
2	301030	322219	342423	361728	380211	397940	414973	431364	447158	462398	**2**
3	477121	491362	505150	518514	531479	544068	556303	568202	579784	591065	**3**
4	602060	612784	623249	633468	643453	653213	662758	672098	681241	690196	**4**
5	698970	707570	716003	724276	732394	740363	748188	755875	763428	770852	**5**
6	778151	785330	792392	799341	806180	812913	819544	826075	832509	838849	**6**
7	845098	851258	957332	863323	869232	875061	880814	886491	892095	897627	**7**
8	903090	908485	913814	919078	924279	929419	934498	939519	944483	949390	**8**
9	954243	959041	963788	968483	973128	977724	982271	986772	991226	995635	**9**
N.	0	1	2	3	4	5	6	7	8	9	N.

N.	0	1	2	3	4	5	6	7	8	9	D.
100	000000	000434	000868	001301	001734	002166	002598	003029	003461	003891	**432**
101	004321	004751	005181	005609	006038	006466	006894	007321	007748	008174	**428**
102	008600	009026	009451	009876	010300	010724	011147	011570	011993	012415	**424**
103	012837	013259	013680	014100	014521	014940	015360	015779	016197	016616	**419**
104	017033	017451	017868	018284	018700	019116	019532	019947	020361	020775	**415**
105	021189	021603	022016	022428	022841	023252	023664	024075	024486	024896	**411**
106	025306	025715	026125	026533	026942	027350	027757	028164	028571	028978	**408**
107	029384	029789	030195	030600	031004	031408	031812	032216	032619	033021	**404**
108	033424	033826	034227	034628	035029	035430	035830	036230	036629	037028	**400**
109	037426	037825	038223	038620	039017	039414	039811	040207	040602	040998	**396**
110	041393	041787	042182	042576	042969	043362	043755	044148	044540	044932	**393**
N.	0	1	2	3	4	5	6	7	8	9	D.

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* See Introduction, *ante*, p. 2.

N.	0	1	2	3	4	5	6	7	8	9	D.
111	045323	045714	046105	046495	046885	047275	047664	048053	048442	048830	389
112	049218	049606	049993	050380	050766	051153	051538	051924	052309	052694	386
113	053078	053463	053846	054230	054613	054996	055378	055760	056142	056524	383
114	056905	057286	057666	058046	058426	058805	059185	059563	059942	060320	379
115	060698	061075	061452	061829	062206	062582	062958	063333	063709	064083	376
116	064458	064832	065206	065580	065953	066326	066699	067071	067443	067815	373
117	068186	068557	068928	069298	069668	070038	070407	070776	071145	071514	369
118	071882	072250	072617	072985	073352	073718	074085	074451	074816	075182	366
119	075547	075912	076276	076640	077004	077368	077731	078094	078457	078819	363
120	079181	079543	079904	080266	080626	080987	081347	081707	082067	082426	360
121	082785	083144	083503	083861	084219	084576	084934	085291	085647	086004	357
122	086360	086716	087071	087426	087781	088136	088490	088845	089198	089552	354
123	089905	090258	090611	090963	091315	091667	092018	092370	092721	093071	351
124	093422	093772	094122	094471	094820	095169	095518	095866	096215	096562	349
125	096910	097257	097604	097951	098298	098644	098990	099335	099681	100026	346
126	100371	100715	101059	101403	101747	102091	102434	102777	103119	103462	343
127	103804	104146	104487	104828	105169	105510	105851	106191	106531	106871	340
128	107210	107549	107888	108227	108565	108903	109241	109579	109916	110253	338
129	110590	110926	111263	111599	111934	112270	112605	112940	113275	113609	335
130	113943	114277	114611	114944	115278	115611	115943	116276	116608	116940	332
131	117271	117603	117934	118265	118595	118926	119256	119586	119915	120245	330
132	120574	120903	121231	121560	121888	122216	122544	122871	123198	123525	327
133	123852	124178	124504	124830	125156	125481	125806	126131	126456	126781	325
134	127105	127429	127753	128076	128399	128722	129045	129368	129690	130012	322
135	130334	130655	130977	131298	131619	131939	132260	132580	132900	133219	320
N.	0	1	2	3	4	5	6	7	8	9	D.

N.	0	1	2	3	4	5	6	7	8	9	D.
136	133539	133858	134177	134496	134814	135133	135451	135769	136086	136403	318
137	136721	137037	137354	137671	137987	138303	138618	138934	139249	139564	315
138	139879	140194	140508	140822	141136	141450	141763	142076	142389	142702	313
139	143015	143327	143639	143951	144263	144574	144885	145196	145507	145818	311
140	146128	146438	146748	147058	147367	147676	147985	148294	148603	148911	309
141	149219	149527	149835	150142	150449	150756	151063	151370	151676	151982	308
142	152288	152594	152900	153205	153510	153815	154120	154424	154728	155032	304
143	155336	155640	155943	156246	156549	156852	157154	157457	157759	158061	302
144	158362	158664	158965	159266	159567	159868	160968	160469	160769	161068	300
145	161368	161667	161967	162266	162564	162863	163161	163460	163758	164055	298
146	164353	164650	164947	165244	165541	165838	166134	166430	166726	167022	296
147	167317	167613	167908	168203	168497	168792	169086	169380	169674	169968	294
148	170262	170555	170848	171141	171434	171726	172019	172311	172603	172895	292
149	173186	173478	173769	174060	174351	174641	174932	175222	175512	175802	290
150	176091	176381	176670	176959	177248	177536	177825	178113	178401	178689	288
151	178977	179264	179552	179839	180126	180413	180699	180986	181272	181558	286
152	181844	182129	182415	182700	182985	183270	183555	183839	184123	184407	284
153	184691	184975	185259	185542	185825	186108	186391	186674	186956	187239	282
154	187521	187803	188084	188366	188647	188928	189209	189490	189771	190051	281
155	190332	190612	190892	191171	191451	191730	192010	192289	192567	192846	279
156	193125	193403	193681	193959	194237	194514	194792	195069	195346	195623	277
157	195900	196176	196453	196729	197005	197281	197556	197832	198107	198382	275
158	198657	198932	199206	199481	199755	200029	200303	200577	200850	201124	274
159	201397	201670	201943	202216	202488	202761	203033	203305	203577	203848	272
160	204120	204391	204663	204934	205204	205475	205746	206016	206286	206556	270
N.	0	1	2	3	4	5	6	7	8	9	D.

N.	0	1	2	3	4	5	6	7	8	9	D.
161	206826	207096	207365	207634	207904	208173	208441	208710	208979	209247	**269**
162	209515	209783	210051	210319	210586	210853	211121	211388	211654	211921	**267**
163	212188	212454	212720	212986	213252	213518	213783	214049	214314	214579	**266**
164	214844	215109	215373	215638	215902	216166	216430	216694	216957	217221	**264**
165	217484	217747	218010	218273	218536	218798	219060	219323	219585	219846	**262**
166	220108	220370	220631	220892	221153	221414	221675	221936	222196	222456	**260**
167	222716	222976	223236	223496	223755	224015	224274	224533	224792	225051	**259**
168	225309	225568	225826	226084	226342	226600	226858	227115	227372	227630	**257**
169	227887	228144	228400	228657	228913	229170	229426	229682	229938	230193	**256**
170	230449	230704	230960	231215	231470	231724	231979	232234	232488	232742	**254**
171	232996	233250	233504	233757	234011	234264	234517	234770	235023	235276	**253**
172	235528	235781	236033	236285	236537	236789	237041	237292	237544	237795	**251**
173	238046	238297	238548	238799	239049	239299	239550	239800	240050	240300	**250**
174	240549	240799	241048	241297	241546	241795	242044	242293	242541	242790	**249**
175	243038	243286	243534	243782	244030	244277	244525	244772	245019	245266	**247**
176	245513	245759	246006	246252	246499	246745	246991	247237	247482	247728	**246**
177	247973	248219	248464	248709	248954	249198	249443	249687	249932	250176	**244**
178	250420	250664	250908	251151	251395	251638	251881	252125	252368	252610	**243**
179	252853	253096	253338	253580	253822	254064	254306	254548	254790	255031	**242**
180	255273	255514	255755	255996	256237	256477	256718	256958	257198	257439	**240**
181	257679	257918	258158	258398	258637	258877	259116	259355	259594	259833	**239**
182	260071	260310	260548	260787	261025	261263	261501	261739	261976	262214	**238**
183	262451	262688	262925	263162	263399	263636	263873	264109	264346	264582	**236**
184	264818	265054	265290	265525	265761	265996	266232	266467	266702	266937	**235**
185	267172	267406	267641	267875	268110	268344	268578	268812	269046	269279	**234**
N.	0	1	2	3	4	5	6	7	8	9	D.

N.	0	1	2	3	4	5	6	7	8	9	D.
186	269513	269746	269980	270213	270446	270679	270912	271144	271377	271609	**233**
187	271842	272074	272306	272538	272770	273001	273233	273464	273696	273927	**232**
188	274158	274389	274620	274850	275081	275311	275542	275772	276002	276232	**230**
189	276462	276692	276921	277151	277380	277609	277838	278067	278296	278525	**229**
190	278754	278982	279211	279439	279667	279895	280123	280351	280578	280806	**228**
191	281033	281261	281488	281715	281942	282169	282396	282622	282849	283075	**227**
192	283301	283527	283753	283979	284205	284431	284656	284882	285107	285332	**225**
193	285557	285782	286007	286232	286456	286681	286905	287130	287354	287578	**224**
194	287802	288026	288249	288473	288696	288920	289143	289366	289589	289812	**223**
195	290035	290257	290480	290702	290925	291147	291369	291591	291813	292034	**222**
196	292256	292478	292699	292920	293141	293363	293584	293804	294025	294246	**221**
197	294466	294687	294907	295127	295347	295567	295787	296007	296226	296446	**219**
198	296665	296884	297104	297323	297542	297761	297979	298198	298416	298635	**218**
199	298853	299071	299289	299507	299725	299943	300161	300378	300595	300813	**217**
200	301030	301247	301464	301681	301898	302114	302331	302547	302764	302980	**216**
201	303196	303412	303628	303844	304059	304275	304491	304706	304921	305136	**215**
202	305351	305566	305781	305996	306211	306425	306639	306854	307068	307282	**214**
203	307496	307710	307924	308137	308351	308564	308778	308991	309204	309417	**213**
204	309630	309843	310056	310268	310481	310693	310906	311118	311330	311542	**212**
205	311754	311966	312177	312389	312600	312812	313023	313234	313445	313656	**211**
206	313867	314078	314289	314499	314710	314920	315130	315340	315551	315760	**210**
207	315970	316180	316390	316599	316809	317018	317227	317436	317646	317854	**209**
208	318063	318272	318481	318689	318898	319106	319314	319522	319730	319938	**208**
209	320146	320354	320562	320769	320977	321184	321391	321598	321805	322012	**207**
210	322219	322426	322633	322839	323046	323252	323458	323665	323871	324077	**206**
N.	0	1	2	3	4	5	6	7	8	9	D.

N.	0	1	2	3	4	5	6	7	8	9	D.
211	324282	324488	324694	324899	325105	325310	325516	325721	325926	326131	**205**
212	326336	326541	326745	326950	327155	327359	327563	327767	327972	328176	**205**
213	328380	328583	328787	328991	329194	329398	329601	329805	330008	330211	**203**
214	330414	330617	330819	331022	331225	331427	331630	331832	332034	332236	**202**
215	332438	332640	332842	333044	333246	333447	333649	333850	334051	334253	**201**
216	334454	334655	334856	335057	335257	335458	335658	335859	336059	336260	**200**
217	336460	336660	336860	337060	337260	337459	337659	337858	338058	338257	**199**
218	338456	338656	338855	339054	339253	339451	339650	339849	340047	340246	**198**
219	340444	340642	340841	341039	341237	341435	341632	341830	342028	342225	**197**
220	342423	342620	342817	343014	343212	343409	343606	343802	343999	344196	**197**
221	344392	344589	344785	344981	345178	345374	345570	345766	345962	346157	**196**
222	346353	346549	346744	346939	347135	347330	347525	347720	347915	348110	**195**
223	348305	348500	348694	348889	349083	349278	349472	349666	349860	350054	**194**
224	350248	350442	350636	350829	351023	351216	351410	351603	351796	351989	**193**
225	352183	352375	352568	352761	352954	353147	353339	353532	353724	353916	**192**
226	354108	354301	354493	354685	354876	355068	355260	355452	355643	355834	**191**
227	356026	356217	356408	356599	356790	356981	357172	357363	357554	357744	**191**
228	357935	358125	358316	358506	358696	358886	359076	359266	359456	359646	**190**
229	359835	360025	360215	360404	360593	360783	360972	361161	361350	361539	**189**
230	361728	361917	362105	362294	362482	362671	362859	363048	363236	363424	**188**
231	363612	363800	363988	364176	364363	364551	364739	364926	365113	365301	**187**
232	365488	365675	365862	366049	366236	366423	366610	366796	366983	367169	**187**
233	367356	367542	367729	367915	368101	368287	368473	368659	368845	369030	**186**
234	369216	369401	369587	369772	369958	370143	370328	370513	370698	370883	**185**
235	371068	371253	371437	371622	371806	371991	372175	372360	372544	372728	**184**
N.	0	1	2	3	4	5	6	7	8	9	D.

N.	0	1	2	3	4	5	6	7	8	9	D.
236	372912	373096	373280	373464	373647	373831	374015	374198	374382	374565	**184**
237	374748	374932	375115	375298	375481	375664	375846	376029	376212	376394	**183**
238	376577	376759	376942	377124	377306	377488	377670	377852	378034	378216	**182**
239	378398	378580	378761	378943	379124	379306	379487	379668	379849	380030	**181**
240	380211	380392	380573	380754	380934	381115	381296	381476	381656	381837	**181**
241	382017	382197	382377	382557	382737	382917	383097	383277	383456	383636	**179**
242	383815	383995	384174	384353	384533	384712	384891	385070	385249	385428	**179**
243	385606	385785	385964	386142	386321	386499	386677	386856	387034	387212	**178**
244	387390	387568	387746	387923	388101	388279	388456	388634	388811	388989	**177**
245	389166	389343	389520	389698	389875	390051	390228	390405	390582	390759	**177**
246	390935	391112	391288	391464	391641	391817	391993	392169	392345	392521	**176**
247	392697	392873	393048	393224	393400	393575	393751	393926	394101	394277	**175**
248	394452	394627	394802	394977	395152	395326	395501	395676	395850	396025	**175**
249	396199	396374	396548	396722	396896	397071	397245	397419	397592	397766	**174**
250	397940	398114	398287	398461	398634	398808	398981	399154	399328	399501	**173**
251	399674	399847	400020	400192	400365	400538	400711	400883	401056	401228	**173**
252	401401	401573	401745	401917	402089	402261	402433	402605	402777	402949	**172**
253	403121	403292	403464	403635	403807	403978	404149	404320	404492	404663	**171**
254	404834	405005	405176	405346	405517	405688	405858	406029	406199	406370	**171**
255	406540	406710	406881	407051	407221	407391	407561	407731	407901	408070	**170**
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638	804821	804889	804957	805025	805093	805161	805229	805297	805365	805433	**68**
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641	806858	806926	806994	807061	807129	807197	807264	807332	807400	807467	**68**
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738	868056	868115	868174	868233	868292	868350	868409	868468	868527	868586	**59**
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755	877947	878004	878062	878119	878177	878234	878292	878349	878407	878464	**57**
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987	994317	994361	994405	994449	994493	994537	994581	994625	994669	994713	**44**
988	994757	994801	994845	994889	994933	994977	995021	995065	995108	995152	**44**
989	995196	995240	995284	995328	995372	995416	995460	995504	995547	995591	**44**
990	995635	995679	995723	995767	995811	995854	995898	995942	995986	996030	**44**
991	996074	996117	996161	996205	996249	996293	996337	996380	996424	996468	**44**
992	996512	996555	996599	996643	996687	996731	996774	996818	996862	996906	**44**
993	996949	996993	997037	997080	997124	997168	997212	997255	997299	997343	**44**
994	997386	997430	997474	997517	997561	997605	997648	997692	997736	997779	**44**
995	997823	997867	997910	997954	997998	998041	998085	998129	998172	998216	**44**
996	998259	998303	998347	998390	998434	998477	998521	998564	998608	998652	**44**
997	998695	998739	998782	998826	998869	998913	998956	999000	999043	999087	**44**
998	999131	999174	999218	999261	999305	999348	999392	999435	999479	999522	**44**
999	999565	999609	999652	999696	999739	999783	999826	999870	999913	999957	**43**
N.	0	1	2	3	4	5	6	7	8	9	D.

TABLE 5.—HYPERBOLIC LOGARITHMS OF NUMBERS FROM 1·01 TO 20.*

No.	Log.	No.	Log.	No.	Log.	No.	Log.
1·01	·0099	**1·42**	·3507	**1·83**	·6043	**2·24**	·8065
1·02	·0198	**1·43**	·3577	**1·84**	·6098	**2·25**	·8109
1·03	·0296	**1·44**	·3646	**1·85**	·6152	**2·26**	·8154
1·04	·0392	**1·45**	·3716	**1·86**	·6206	**2·27**	·8198
1·05	·0488	**1·46**	·3784	**1·87**	·6259	**2·28**	·8242
1·06	·0583	**1·47**	·3853	**1·88**	·6313	**2·29**	·8286
1·07	·0677	**1·48**	·3920	**1·89**	·6366	**2·30**	·8329
1·08	·0770	**1·49**	·3988	**1·90**	·6419	**2·31**	·8372
1·09	·0862	**1·50**	·4055	**1·91**	·6471	**2·32**	·8416
1·10	·0953	**1·51**	·4121	**1·92**	·6523	**2·33**	·8458
1·11	·1044	**1·52**	·4187	**1·93**	·6575	**2·34**	·8502
1·12	·1133	**1·53**	·4253	**1·94**	·6627	**2·35**	·8544
1·13	·1222	**1·54**	·4318	**1·95**	·6678	**2·36**	·8587
1·14	·1310	**1·55**	·4383	**1·96**	·6729	**2·37**	·8629
1·15	·1398	**1·56**	·4447	**1·97**	·6780	**2·38**	·8671
1·16	·1484	**1·57**	·4511	**1·98**	·6831	**2·39**	·8713
1·17	·1570	**1·58**	·4574	**1·99**	·6881	**2·40**	·8755
1·18	·1655	**1·59**	·4637	**2·00**	·6931	**2·41**	·8796
1·19	·1740	**1·60**	·4700	**2·01**	·6981	**2·42**	·8838
1·20	·1823	**1·61**	·4762	**2·02**	·7031	**2·43**	·8879
1·21	·1906	**1·62**	·4824	**2·03**	·7080	**2·44**	·8920
1·22	·1988	**1·63**	·4886	**2·04**	·7129	**2·45**	·8961
1·23	·2070	**1·64**	·4947	**2·05**	·7178	**2·46**	·9002
1·24	·2151	**1·65**	·5008	**2·06**	·7227	**2·47**	·9042
1·25	·2231	**1·66**	·5068	**2·07**	·7275	**2·48**	·9083
1·26	·2311	**1·67**	·5128	**2·08**	·7324	**2·49**	·9123
1·27	·2390	**1·68**	·5188	**2·09**	·7372	**2·50**	·9163
1·28	·2469	**1·69**	·5247	**2·10**	·7419	**2·51**	·9203
1·29	·2546	**1·70**	·5306	**2·11**	·7467	**2·52**	·9243
1·30	·2624	**1·71**	·5365	**2·12**	·7514	**2·53**	·9282
1·31	·2700	**1·72**	·5423	**2·13**	·7561	**2·54**	·9322
1·32	·2776	**1·73**	·5481	**2·14**	·7608	**2·55**	·9361
1·33	·2852	**1·74**	·5539	**2·15**	·7655	**2·56**	·9400
1·34	·2927	**1·75**	·5596	**2·16**	·7701	**2·57**	·9439
1·35	·3001	**1·76**	·5653	**2·17**	·7747	**2·58**	·9478
1·36	·3075	**1·77**	·5710	**2·18**	·7793	**2·59**	·9517
1·37	·3148	**1·78**	·5766	**2·19**	·7839	**2·60**	·9555
1·38	·3221	**1·79**	·5822	**2·20**	·7885	**2·61**	·9594
1·39	·3293	**1·80**	·5878	**2·21**	7930	**2·62**	·9632
1·40	·3365	**1·81**	·5933	**2·22**	·7975	**2·63**	·9670
1·41	·3436	**1·82**	·5988	**2·23**	·8020	**2·64**	·9708

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* See Introduction, *ante*, p. 6.

No.	Log.	No.	Log.	No.	Log.	No.	Log.
2·65	·9746	**3·08**	1·1249	**3·51**	1·2556	**3·94**	1·3712
2·66	·9783	**3·09**	1·1282	**3·52**	1·2585	**3·95**	1·3737
2·67	·9821	**3·10**	1·1314	**3·53**	1·2613	**3·96**	1·3762
2·68	·9858	**3·11**	1·1346	**3·54**	1·2641	**3·97**	1·3788
2·69	·9895	**3·12**	1·1378	**3·55**	1·2669	**3·98**	1·3813
2·70	·9933	**3·13**	1·1410	**3·56**	1·2698	**3·99**	1·3838
2·71	·9969	**3·14**	1·1442	**3·57**	1·2726	**4·00**	1·3863
2·72	1·0006	**3·15**	1·1474	**3·58**	1·2754	**4·01**	1·3888
2·73	1·0043	**3·16**	1·1506	**3·59**	1·2782	**4·02**	1·3913
2·74	1·0080	**3·17**	1·1537	**3·60**	1·2809	**4·03**	1·3938
2·75	1·0116	**3·18**	1·1569	**3·61**	1·2837	**4·04**	1·3962
2·76	1·0152	**3·19**	1·1600	**3·62**	1·2865	**4·05**	1·3987
2·77	1·0188	**3·20**	1·1632	**3·63**	1·2892	**4·06**	1·4012
2·78	1·0225	**3·21**	1·1663	**3·64**	1·2920	**4·07**	1·4036
2·79	1·0260	**3·22**	1·1694	**3·65**	1·2947	**4·08**	1·4061
2·80	1·0296	**3·23**	1·1725	**3·66**	1·2975	**4·09**	1·4085
2·81	1·0332	**3·24**	1·1756	**3·67**	1·3002	**4·10**	1·4110
2·82	1·0367	**3·25**	1·1787	**3·68**	1·3029	**4·11**	1·4134
2·83	1·0403	**3·26**	1·1817	**3·69**	1·3056	**4·12**	1·4159
2·84	1·0438	**3·27**	1·1848	**3·70**	1·3083	**4·13**	1·4183
2·85	1·0473	**3·28**	1·1878	**3·71**	1·3110	**4·14**	1·4207
2·86	1·0508	**3·29**	1·1909	**3·72**	1·3137	**4·15**	1·4231
2·87	1·0543	**3·30**	1·1939	**3·73**	1·3164	**4·16**	1·4255
2·88	1·0578	**3·31**	1·1969	**3·74**	1·3191	**4·17**	1·4279
2·89	1·0613	**3·32**	1·1999	**3·75**	1·3218	**4·18**	1·4303
2·90	1·0647	**3·33**	1·2030	**3·76**	1·3244	**4·19**	1·4327
2·91	1·0682	**3·34**	1·2060	**3·77**	1·3271	**4·20**	1·4351
2·92	1·0716	**3·35**	1·2090	**3·78**	1·3297	**4·21**	1·4375
2·93	1·0750	**3·36**	1·2119	**3·79**	1·3324	**4·22**	1·4398
2·94	1·0784	**3·37**	1·2149	**3·80**	1·3350	**4·23**	1·4422
2·95	1·0813	**3·38**	1·2179	**3·81**	1·3376	**4·24**	1·4446
2·96	1·0852	**3·39**	1·2208	**3·82**	1·3403	**4·25**	1·4469
2·97	1·0886	**3·40**	1·2238	**3·83**	1·3429	**4·26**	1·4493
2·98	1·0919	**3·41**	1·2267	**3·84**	1·3455	**4·27**	1·4516
2·99	1·0953	**3·42**	1·2296	**3·85**	1·3481	**4·28**	1·4540
3·00	1·0986	**3·43**	1·2326	**3·86**	1·3507	**4·29**	1·4563
3·01	1·1019	**3·44**	1·2355	**3·87**	1·3533	**4·30**	1·4586
3·02	1·1053	**3·45**	1·2384	**3·88**	1·3558	**4·31**	1·4609
3·03	1·1086	**3·46**	1·2413	**3·89**	1·3584	**4·32**	1·4633
3·04	1·1119	**3·47**	1·2442	**3·90**	1·3610	**4·33**	1·4656
3·05	1·1151	**3·48**	1·2470	**3·91**	1·3635	**4·34**	1·4679
3·06	1·1184	**3·49**	1·2499	**3·92**	1·3661	**4·35**	1·4702
3·07	1·1217	**3·50**	1·2528	**3·93**	1·3686	**4·36**	1·4725

No.	Log.	No.	Log.	No.	Log.	No.	Log.
4·37	1·4748	4·80	1·5686	5·23	1·6544	5·66	1·7334
4·38	1·4770	4·81	1·5707	5·24	1·6563	5·67	1·7352
4·39	1·4793	4·82	1·5728	5·25	1·6582	5·68	1·7370
4·40	1·4816	4·83	1·5748	5·26	1·6601	5·69	1·7387
4·41	1·4839	4·84	1·5769	5·27	1·6620	5·70	1·7405
4·42	1·4861	4·85	1·5790	5·28	1·6639	5·71	1·7422
4·43	1·4884	4·86	1·5810	5·29	1·6658	5·72	1·7440
4·44	1·4907	4·87	1·5831	5·30	1·6677	5·73	1·7457
4·45	1·4929	4·88	1·5851	5·31	1·6696	5·74	1·7475
4·46	1·4951	4·89	1·5872	5·32	1·6715	5·75	1·7492
4·47	1·4974	4·90	1·5892	5·33	1·6734	5·76	1·7509
4·48	1·4996	4·91	1·5913	5·34	1·6752	5·77	1·7527
4·49	1·5019	4·92	1·5933	5·35	1·6771	5·78	1·7544
4·50	1·5041	4·93	1·5953	5·36	1·6790	5·79	1·7561
4·51	1·5063	4·94	1·5974	5·37	1·6808	5·80	1·7579
4·52	1·5085	4·95	1·5994	5·38	1·6827	5·81	1·7596
4·53	1·5107	4·96	1·6014	5·39	1·6845	5·82	1·7613
4·54	1·5129	4·97	1·6034	5·40	1·6864	5·83	1·7630
4·55	1·5151	4·98	1·6054	5·41	1·6882	5·84	1·7647
4·56	1·5173	4·99	1·6074	5·42	1·6901	5·85	1·7664
4·57	1·5195	5·00	1·6094	5·43	1·6919	5·86	1·7681
4·58	1·5217	5·01	1·6114	5·44	1·6938	5·87	1·7699
4·59	1·5239	5·02	1·6134	5·45	1·6956	5·88	1·7716
4·60	1·5261	5·03	1·6154	5·46	1·6974	5·89	1·7733
4·61	1·5282	5·04	1·6174	5·47	1·6993	5·90	1·7750
4·62	1·5304	5·05	1·6194	5·48	1·7011	5·91	1·7766
4·63	1·5326	5·06	1·6214	5·49	1·7029	5·92	1·7783
4·64	1·5347	5·07	1·6233	5·50	1·7047	5·93	1·7800
4·65	1·5369	5·08	1·6253	5·51	1·7066	5·94	1·7817
4·66	1·5390	5·09	1·6273	5·52	1·7084	5·95	1·7834
4·67	1·5412	5·10	1·6292	5·53	1·7102	5·96	1·7851
4·68	1·5433	5·11	1·6312	5·54	1·7120	5·97	1·7867
4·69	1·5454	5·12	1·6332	5·55	1·7138	5·98	1·7884
4·70	1·5476	5·13	1·6351	5·56	1·7156	5·99	1·7901
4·71	1·5497	5·14	1·6371	5·57	1·7174	6·00	1·7918
4·72	1·5518	5·15	1·6390	5·58	1·7192	6·01	1·7934
4·73	1·5539	5·16	1·6409	5·59	1·7210	6·02	1·7951
4·74	1·5560	5·17	1·6429	5·60	1·7228	6·03	1·7967
4·75	1·5581	5·18	1·6448	5·61	1·7246	6·04	1·7984
4·76	1·5602	5·19	1·6467	5·62	1·7263	6·05	1·8001
4·77	1·5623	5·20	1·6487	5·63	1·7281	6·06	1·8017
4·78	1·5644	5·21	1·6506	5·64	1·7299	6·07	1·8034
4·79	1·5665	5·22	1·6525	5·65	1·7317	6·08	1·8050

No.	Log.	No.	Log.	No.	Log.	No.	Log.
6·09	1·8066	**6·52**	1·8749	**6·95**	1·9387	**7·38**	1·9988
6·10	1·8083	**6·53**	1·8764	**6·96**	1·9402	**7·39**	2·0001
6·11	1·8099	**6·54**	1·8779	**6·97**	1·9416	**7·40**	2·0015
6·12	1·8116	**6·55**	1·8795	**6·98**	1·9430	**7·41**	2·0028
6·13	1·8132	**6·56**	1·8810	**6·99**	1·9445	**7·42**	2·0042
6·14	1·8148	**6·57**	1·8825	**7·00**	1·9459	**7·43**	2·0055
6·15	1·8165	**6·58**	1·8840	**7·01**	1·9473	**7·44**	2·0069
6·16	1·8181	**6·59**	1·8856	**7·02**	1·9488	**7·45**	2·0082
6·17	1·8197	**6·60**	1·8871	**7·03**	1·9502	**7·46**	2·0096
6·18	1·8213	**6·61**	1·8886	**7·04**	1·9516	**7·47**	2·0109
6·19	1·8229	**6·62**	1·8901	**7·05**	1·9530	**7·48**	2·0122
6·20	1·8245	**6·63**	1·8916	**7·06**	1·9544	**7·49**	2·0136
6·21	1·8262	**6·64**	1·8931	**7·07**	1·9559	**7·50**	2·0149
6·22	1·8278	**6·65**	1·8946	**7·08**	1·9573	**7·51**	2·0162
6·23	1·8294	**6·66**	1·8961	**7·09**	1·9587	**7·52**	2·0176
6·24	1·8310	**6·67**	1·8976	**7·10**	1·9601	**7·53**	2·0189
6·25	1·8326	**6·68**	1·8991	**7·11**	1·9615	**7·54**	2·0202
6·26	1·8342	**6·69**	1·9006	**7·12**	1·9629	**7·55**	2·0215
6·27	1·8358	**6·70**	1·9021	**7·13**	1·9643	**7·56**	2·0229
6·28	1·8374	**6·71**	1·9036	**7·14**	1·9657	**7·57**	2·0242
6·29	1·8390	**6·72**	1·9051	**7·15**	1·9671	**7·58**	2·0255
6·30	1·8405	**6·73**	1·9066	**7·16**	1·9685	**7·59**	2·0268
6·31	1·8421	**6·74**	1·9081	**7·17**	1·9699	**7·60**	2·0281
6·32	1·8437	**6·75**	1·9095	**7·18**	1·9713	**7·61**	2·0295
6·33	1·8453	**6·76**	1·9110	**7·19**	1·9727	**7·62**	2·0308
6·34	1·8469	**6·77**	1·9125	**7·20**	1·9741	**7·63**	2·0321
6·35	1·8485	**6·78**	1·9140	**7·21**	1·9755	**7·64**	2·0334
6·36	1·8500	**6·79**	1·9155	**7·22**	1·9769	**7·65**	2·0347
6·37	1·8516	**6·80**	1·9169	**7·23**	1·9782	**7·66**	2·0360
6·38	1·8532	**6·81**	1·9184	**7·24**	1·9796	**7·67**	2·0373
6·39	1·8547	**6·82**	1·9199	**7·25**	1·9810	**7·68**	2·0386
6·40	1·8563	**6·83**	1·9213	**7·26**	1·9824	**7·69**	2·0399
6·41	1·8579	**6·84**	1·9228	**7·27**	1·9838	**7·70**	2·0412
6·42	1·8594	**6·85**	1·9242	**7·28**	1·9851	**7·71**	2·0425
6·43	1·8610	**6·86**	1·9257	**7·29**	1·9865	**7·72**	2·0438
6·44	1·8625	**6·87**	1·9272	**7·30**	1·9879	**7·73**	2·0451
6·45	1·8641	**6·88**	1·9286	**7·31**	1·9892	**7·74**	2·0464
6·46	1·8656	**6·89**	1·9301	**7·32**	1·9906	**7·75**	2·0477
6·47	1·8672	**6·90**	1·9315	**7·33**	1·9920	**7·76**	2·0490
6·48	1·8687	**6·91**	1·9330	**7·34**	1·9933	**7·77**	2·0503
6·49	1·8703	**6·92**	1·9344	**7·35**	1·9947	**7·78**	2·0516
6·50	1·8718	**6·93**	1·9359	**7·36**	1·9961	**7·79**	2·0528
6·51	1·8733	**6·94**	1·9373	**7·37**	1·9974	**7·80**	2·0541

No.	Log.	No.	Log.	No.	Log.	No.	Log.
7·81	2·0554	**8·24**	2·1090	**8·67**	2·1599	**9·10**	2·2083
7·82	2·0567	**8·25**	2·1102	**8·68**	2·1610	**9·11**	2·2094
7·83	2·0580	**8·26**	2·1114	**8·69**	2·1622	**9·12**	2·2105
7·84	2·0592	**8·27**	2·1126	**8·70**	2·1633	**9·13**	2·2116
7·85	2·0605	**8·28**	2·1138	**8·71**	2·1645	**9·14**	2·2127
7·86	2·0618	**8·29**	2·1150	**8·72**	2·1656	**9·15**	2·2138
7·87	2·0631	**8·30**	2·1163	**8·73**	2·1668	**9·16**	2·2148
7·88	2·0643	**8·31**	2·1175	**8·74**	2·1679	**9·17**	2·2159
7·89	2·0656	**8·32**	2·1187	**8·75**	2·1691	**9·18**	2·2170
7·90	2·0669	**8·33**	2·1199	**8·76**	2·1702	**9·19**	2·2181
7·91	2·0681	**8·34**	2·1211	**8·77**	2·1713	**9·20**	2·2192
7·92	2·0694	**8·35**	2·1223	**8·78**	2·1725	**9·21**	2·2203
7·93	2·0707	**8·36**	2·1235	**8·79**	2·1736	**9·22**	2·2214
7·94	2·0719	**8·37**	2·1247	**8·80**	2·1748	**9·23**	2·2225
7·95	2·0732	**8·38**	2·1258	**8·81**	2·1759	**9·24**	2·2235
7·96	2·0744	**8·39**	2·1270	**8·82**	2·1770	**9·25**	2·2246
7·97	2·0757	**8·40**	2·1282	**8·83**	2·1782	**9·26**	2·2257
7·98	2·0769	**8·41**	2·1294	**8·84**	2·1793	**9·27**	2·2268
7·99	2·0782	**8·42**	2·1306	**8·85**	2·1804	**9·28**	2·2279
8·00	2·0794	**8·43**	2·1318	**8·86**	2·1815	**9·29**	2·2289
8·01	2·0807	**8·44**	2·1330	**8·87**	2·1827	**9·30**	2·2300
8·02	2·0819	**8·45**	2·1342	**8·88**	2·1838	**9·31**	2·2311
8·03	2·0832	**8·46**	2·1353	**8·89**	2·1849	**9·32**	2·2322
8·04	2·0844	**8·47**	2·1365	**8·90**	2·1861	**9·33**	2·2332
8·05	2·0857	**8·48**	2·1377	**8·91**	2·1872	**9·34**	2·2343
8·06	2·0869	**8·49**	2·1389	**8·92**	2·1883	**9·35**	2·2354
8·07	2·0882	**8·50**	2·1401	**8·93**	2·1894	**9·36**	2·2364
8·08	2·0894	**8·51**	2·1412	**8·94**	2·1905	**9·37**	2·2375
8·09	2·0906	**8·52**	2·1424	**8·95**	2·1917	**9·38**	2·2386
8·10	2·0919	**8·53**	2·1436	**8·96**	2·1928	**9·39**	2·2396
8·11	2·0931	**8·54**	2·1448	**8·97**	2·1939	**9·40**	2·2407
8·12	2·0943	**8·55**	2·1459	**8·98**	2·1950	**9·41**	2·2418
8·13	2·0956	**8·56**	2·1471	**9·99**	2·1961	**9·42**	2·2428
8·14	2·0968	**8·57**	2·1483	**9·00**	2·1972	**9·43**	2·2439
8·15	2·0980	**8·58**	2·1494	**9·01**	2·1983	**9·44**	2·2450
8·16	2·0992	**8·59**	2·1506	**9·02**	2·1994	**9·45**	2·2460
8·17	2·1005	**8·60**	2·1518	**9·03**	2·2006	**9·46**	2·2471
8·18	2·1017	**8·61**	2·1529	**9·04**	2·2017	**9·47**	2·2481
8·19	2·1029	**8·62**	2·1541	**9·05**	2·2028	**9·48**	2·2492
8·20	2·1041	**8·63**	2·1552	**9·06**	2·2039	**9·49**	2·2502
8·21	2·1054	**8·64**	2·1564	**9·07**	2·2050	**9·50**	2·2513
8·22	2·1066	**8·65**	2·1576	**9·08**	2·2061	**9·51**	2·2523
8·23	2·1078	**8·66**	2·1587	**9·09**	2·2072	**9·52**	2·2534

No.	Log.	No.	Log.	No.	Log.	No.	Log.
9·53	2·2544	**9·73**	2·2752	**9·93**	2·2956	**13·25**	2·5840
9·54	2·2555	**9·74**	2·2762	**9·94**	2·2966	**13·50**	2·6027
9·55	2·2565	**9·75**	2·2773	**9·95**	2·2976	**13·75**	2·6211
9·56	2·2576	**9·76**	2·2783	**9·96**	2·2986	**14·00**	2·6391
9·57	2·2586	**9·77**	2·2793	**9·97**	2·2996	**14·25**	2·6567
9·58	2·2597	**9·78**	2·2803	**9·98**	2·3006	**14·50**	2·6740
9·59	2·2607	**9·79**	2·2814	**9·99**	2·3016	**14·75**	2·6913
9·60	2·2618	**9·80**	2·2824	**10·00**	2·3026	**15·00**	2·7081
9·61	2·2628	**9·81**	2·2834	**10·25**	2·3279	**15·50**	2·7408
9·62	2·2638	**9·82**	2·2844	**10·50**	2·3513	**16·00**	2·7726
9·63	2·2649	**9·83**	2·2854	**10·75**	2·3749	**16·50**	2·8034
9·64	2·2659	**9·84**	2·2865	**11·00**	2·3979	**17·00**	2·8332
9·65	2·2670	**9·85**	2·2875	**11·25**	2·4201	**17·50**	2·8621
9·66	2·2680	**9·86**	2·2885	**11·50**	2·4430	**18·00**	2·8904
9·67	2·2690	**9·87**	2·2895	**11·75**	2·4636	**18·50**	2·9173
9·68	2·2701	**9·88**	2·2905	**12·00**	2·4849	**19·00**	2·9444
9·69	2·2711	**9·89**	2·2915	**12·25**	2·5052	**19·50**	2·9703
9·70	2·2721	**9·90**	2·2925	**12·50**	2·5262	**20·00**	2·9957
9·71	2·2732	**9·91**	2·2985	**12·75**	2·5455		
9·72	2·2742	**9·92**	2·2946	**13·00**	2·5649		

TABLE 6.—SINES AND COSINES OF ANGLES FROM 0° TO 90°.*

(RADIUS = 1.)

Sines of Angles.	Cosines of Angles.	Values.	Sines of Angles.	Cosines of Angles.	Values.
°	°		°	°	
0	90	·00000	5·5	84·5	·09585
0·5	89·5	·00873	6	84	·10453
1	89	·01745	6·5	83·5	·11320
1·5	88·5	·02618	7	83	·12187
2	88	·03490	7·5	82·5	·13053
2·5	87·5	·04362	8	82	·13917
3	87	·05234	8·5	81·5	·14781
3·5	86·5	·06105	9	81	·15643
4	86	·06976	9·5	80·5	·16505
4·5	85·5	·07846	10	80	·17365
5	85	·08716	10·5	79·5	·18224

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* See Introduction, *ante*, p. 6.

Sines of Angles.	Cosines of Angles.	Values.	Sines of Angles.	Cosines of Angles.	Values.
°	°		°	°	
11	79	·19081	31·5	58·5	·52250
11·5	78·5	·19937	32	58	·52992
12	78	·20791	32·5	57·5	·53730
12·5	77·5	·21644	33	57	·54464
13	77	·22495	33·5	56·5	·55194
13·5	76·5	·23344	34	56	·55919
14	76	·24192	34·5	55·5	·56641
14·5	75·5	·25038	35	55	·57358
15	75	·25882	35·5	54·5	·58070
15·5	74·5	·26724	36	54	·58778
16	74	·27564	36·5	53·5	·59482
16·5	73·5	·28401	37	53	·60181
17	73	·29237	37·5	52·5	·60876
17·5	72·5	·30071	38	52	·61566
18	72	·30902	38·5	51·5	·62251
18·5	71·5	·31730	39	51	·62932
19	71	·32557	39·5	50·5	·63608
19·5	70·5	·33381	40	50	·64279
20	70	·34202	40·5	49·5	·64945
20·5	69·5	·35021	41	49	·65606
21	69	·35837	41·5	48·5	·66262
21·5	68·5	·36650	42	48	·66913
22	68	·37461	42·5	47·5	·67559
22·5	67·5	·38268	43	47	·68200
23	67	·39073	43·5	46·5	·68835
23·5	66·5	·39875	44	46	·69466
24	66	·40674	44·5	45·5	·70091
24·5	65·5	·41469	45	45	·70711
25	65	·42262	45·5	44·5	·71325
25·5	64·5	·43051	46	44	·71934
26	64	·43837	46·5	43·5	·72537
26·5	63·5	·44620	47	43	·73135
27	63	·45399	47·5	42·5	·73728
27·5	62·5	·46175	48	42	·74314
28	62	·46947	48·5	41·5	·74896
28·5	61·5	·47716	49	41	·75471
29	61	·48481	49·5	40·5	·76041
29·5	60·5	·49242	50	40	·76604
30	60	·50000	50·5	39·5	·77162
30·5	59·5	·50754	51	39	·77715
31	59	·51504	51·5	38·5	·78261

Sines of Angles.	Cosines of Angles.	Values.
°	°	
52	38	·78801
52·5	37·5	·79335
53	37	·79864
53·5	36·5	·80386
54	36	·80902
54·5	35·5	·81412
55	35	·81915
55·5	34·5	·82413
56	34	·82904
56·5	33·5	·83389
57	33	·83867
57·5	32·5	·84339
58	32	·84805
58·5	31·5	·85264
59	31	·85717
59·5	30·5	·86163
60	30	·86602
60·5	29·5	·87036
61	29	·87462
61·5	28·5	·87882
62	28	·88295
62·5	27·5	·88701
63	27	·89101
63·5	26·5	·89493
64	26	·89879
64·5	25·5	·90258
65	25	·90631
65·5	24·5	·90996
66	24	·91354
66·5	23·5	·91706
67	23	·92050
67·5	22·5	·92388
68	22	·92718
68·5	21·5	·93042
69	21	·93358
69·5	20·5	·93667
70	20	·93969
70·5	19·5	·94264
71	19	·94552
71·5	18·5	·94832
72	18	·95106
72·5	17·5	·95372
73	17	·95630
73·5	16·5	·95882
74	16	·96126
74·5	15·5	·96363
75	15	·96593
75·5	14·5	·96815
76	14	·97030
76·5	13·5	·97237
77	13	·97437
77·5	12·5	·97630
78	12	·97815
78·5	11·5	·97992
79	11	·98163
79·5	10·5	·98325
80	10	·98481
80·5	9·5	·98629
81	9	·98769
81·5	8·5	·98902
82	8	·99027
82·5	7·5	·99144
83	7	·99255
83·5	6·5	·99357
84	6	·99452
84·5	5·5	·99540
85	5	·99619
85·5	4·5	·99692
86	4	·99756
86·5	3·5	·99813
87	3	·99863
87·5	2·5	·99905
88	2	·99939
88·5	1·5	·99966
89	1	·99985
89·5	0·5	·99996
90	0	1·00000

TABLE 7.—TANGENTS AND COTANGENTS OF ANGLES FROM 0° TO 90°.*

(RADIUS = 1.)

Tangents of Angles.	Cotangents of Angles.	Values.	Tangents of Angles.	Cotangents of Angles.	Values.
°	°		°	°	
0	90	·00000	18·5	71·5	·33459
0·5	89·5	·00873	19	71	·34433
1	89	·01745	19·5	70·5	·35412
1·5	88·5	·02619	20	70	·36397
2	88	·03492	20·5	69·5	·37388
2·5	87·5	·04366	21	69	·38386
3	87	·05241	21·5	68·5	·39391
3·5	86·5	·06116	22	68	·40403
4	86	·06993	22·5	67·5	·41421
4·5	85·5	·07870	23	67	·42447
5	85	·08749	23·5	66·5	·43481
5·5	84·5	·09629	24	66	·44523
6	84	·10510	24·5	65·5	·45573
6·5	83·5	·11394	25	65	·46631
7	83	·12278	25·5	64·5	·47698
7·5	82·5	·13165	26	64	·48773
8	82	·14054	26·5	63·5	·49858
8·5	81·5	·14945	27	63	·50952
9	81	·15838	27·5	62·5	·52057
9·5	80·5	·16734	28	62	·53171
10	80	·17633	28·5	61·5	·54296
10·5	79·5	·18534	29	61	·55431
11	79	·19438	29·5	60·5	·56577
11·5	78·5	·20345	30	60	·57735
12	78	·21256	30·5	59·5	·58904
12·5	77·5	·22169	31	59	·60086
13	77	·23087	31·5	58·5	·61280
13·5	76·5	·24008	32	58	·62487
14	76	·24933	32·5	57·5	·63708
14·5	75·5	·25862	33	57	·64941
15	75	·26795	33·5	56·5	·66189
15·5	74·5	·27732	34	56	·67451
16	74	·28674	34·5	55·5	·68728
16·5	73·5	·29621	35	55	·70021
17	73	·30573	35·5	54·5	·71329
17·5	72·5	·31530	36	54	·72654
18	72	·32492	36·5	53·5	·73996

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* See Introduction, *ante*, p. 6.

Tangents of Angles.	Cotangents of Angles.	Values.	Tangents of Angles.	Cotangents of Angles.	Values.
°	°		°	°	
37	53	·75355	57·5	32·5	1·56969
37·5	52·5	·76763	58	32	1·60033
38	52	·78129	58·5	31·5	1·63185
38·5	51·5	·79544	59	31	1·66428
39	51	·80978	59·5	30·5	1·69766
39·5	50·5	·82434	60	30	1·73205
40	50	·83910	60·5	29·5	1·76749
40·5	49·5	·85408	61	29	1·80405
41	49	·86929	61·5	28·5	1·84174
41·5	48·5	·88472	62	28	1·88073
42	48	·90040	62·5	27·5	1·92098
42·5	47·5	·91633	63	27	1·96261
43	47	·93251	63·5	26·5	2·00569
43·5	46·5	·94896	64	26	2·05030
44	46	·96569	64·5	25·5	2·09654
44·5	45·5	·98270	65	25	2·14451
45	45	1·00000	65·5	24·5	2·19430
45·5	44·5	1·01761	66	24	2·24604
46	44	1·03553	66·5	23·5	2·29984
46·5	43·5	1·05378	67	23	2·35585
47	43	1·07237	67·5	22·5	2·41421
47·5	42·5	1·09131	68	22	2·47509
48	42	1·11061	68·5	21·5	2·53865
48·5	41·5	1·13029	69	21	2·60509
49	41	1·15037	69·5	20·5	2·67462
49·5	40·5	1·17085	70	20	2·74748
50	40	1·19175	70·5	19·5	2·82391
50·5	39·5	1·21310	71	19	2·90421
51	39	1·23490	71·5	18·5	2·98868
51·5	38·5	1·25717	72	18	3·07768
52	38	1·27994	72·5	17·5	3·17159
52·5	37·5	1·30323	73	17	3·27085
53	37	1·32704	73·5	16·5	3·37594
53·5	36·5	1·35142	74	16	3·48741
54	36	1·37638	74·5	15·5	3·60588
54·5	35·5	1·40195	75	15	3·73205
55	35	1·42815	75·5	14·5	3·86671
55·5	34·5	1·45501	76	14	4·01078
56	34	1·48256	76·5	13·5	4·16530
56·5	33·5	1·51084	77	13	4·33148
57	33	1·53986	77·5	12·5	4·51071

Tangents of Angles.	Cotangents of Angles.	Values.	Tangents of Angles.	Cotangents of Angles.	Values.
°	°		°	°	
78	12	4·70463	84·5	5·5	10·38540
78·5	11·5	4·91516	85	5	11·43005
79	11	5·14455	85·5	4·5	12·70620
79·5	10·5	5·39552	86	4	14·30067
80	10	5·67128	86·5	3·5	16·34985
80·5	9·5	5·97576	87	3	19·08114
81	9	6·31375	87·5	2·5	22·90377
81·5	8·5	6·69116	88	2	28·63625
82	8	7·11537	88·5	1·5	38·18846
82·5	7·5	7·59575	89	1	57·28996
83	7	8·14435	89·5	0·5	114·58865
83·5	6·5	8·77689	90	0	infinite.
84	6	9·51436			

Table 8.—Lengths of Circular Arcs from 1° to 180°.*
(Radius = 1.)

Deg.	Length.	Deg.	Length.	Deg.	Length.	Deg.	Length.
1	·0175	**20**	·3491	**39**	·6807	**58**	1·0123
2	·0349	**21**	·3665	**40**	·6981	**59**	1·0297
3	·0524	**22**	·3840	**41**	·7156	**60**	1·0472
4	·0698	**23**	·4014	**42**	·7330	**61**	1·0647
5	·0873	**24**	·4189	**43**	·7505	**62**	1·0821
6	·1047	**25**	·4363	**44**	·7679	**63**	1·0996
7	·1222	**26**	·4538	**45**	·7854	**64**	1·1170
8	·1396	**27**	·4712	**46**	·8029	**65**	1·1345
9	·1571	**28**	·4887	**47**	·8203	**66**	1·1519
10	·1745	**29**	·5061	**48**	·8378	**67**	1·1694
11	·1920	**30**	·5236	**49**	·8552	**68**	1·1868
12	·2094	**31**	·5411	**50**	·8727	**69**	1·2043
13	·2269	**32**	·5585	**51**	·8901	**70**	1·2217
14	·2443	**33**	·5760	**52**	·9076	**71**	1·2392
15	·2618	**34**	·5934	**53**	·9250	**72**	1·2566
16	·2793	**35**	·6109	**54**	·9425	**73**	1·2741
17	·2967	**36**	·6283	**55**	·9599	**74**	1·2915
18	·3142	**37**	·6458	**56**	·9774	**75**	1·3090
19	·3316	**38**	·6632	**57**	·9948	**76**	1·3265

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* See Introduction, *ante*, p. 7.

Deg.	Length.	Deg.	Length.	Deg.	Length.	Deg.	Length.
77	1·3439	**103**	1·7977	**129**	2·2515	**155**	2·7053
78	1·3613	**104**	1·8151	**130**	2·2690	**156**	2·7227
79	1·3788	**105**	1·8326	**131**	2·2864	**157**	2·7402
80	1·3963	**106**	1·8500	**132**	2·3038	**158**	2·7576
81	1·4137	**107**	1·8675	**133**	2·3213	**159**	2·7751
82	1·4312	**108**	1·8850	**134**	2·3387	**160**	2·7925
83	1·4486	**109**	1·9024	**135**	2·3562	**161**	2·8100
84	1·4661	**110**	1·9199	**136**	2·3736	**162**	2·8274
85	1·4835	**111**	1·9373	**137**	2·3911	**163**	2·8449
86	1·5010	**112**	1·9548	**138**	2·4086	**164**	2·8623
87	1·5184	**113**	1·9722	**139**	2·4260	**165**	2·8798
88	1·5359	**114**	1·9897	**140**	2·4435	**166**	2·8912
89	1·5533	**115**	2·0071	**141**	2·4609	**167**	2·9147
90	1·5708	**116**	2·0246	**142**	2·4784	**168**	2·9321
91	1·5882	**117**	2·0420	**143**	2·4958	**169**	2·9496
92	1·6057	**118**	2·0595	**144**	2·5133	**170**	2·9671
93	1·6232	**119**	2·0769	**145**	2·5307	**171**	2·9845
94	1·6406	**120**	2·0944	**146**	2·5482	**172**	3·0020
95	1·6581	**121**	2·1118	**147**	2·5656	**173**	3·0194
96	1·6755	**122**	2·1293	**148**	2·5831	**174**	3·0369
97	1·6930	**123**	2·1468	**149**	2·6005	**175**	3·0543
98	1·7104	**124**	2·1642	**150**	2·6180	**176**	3·0718
99	1·7279	**125**	2·1817	**151**	2·6354	**177**	3·0892
100	1·7453	**126**	2·1991	**152**	2·6529	**178**	3·1067
101	1·7628	**127**	2·2166	**153**	2·6704	**179**	3·1241
102	1·7802	**128**	2·2304	**154**	2·6878	**180**	3·1416

TABLE 9.—LENGTHS OF CIRCULAR ARCS, UP TO A SEMI-CIRCLE.*

(CHORD = 1.)

Height.	Length.	Height.	Length.	Height.	Length.	Height.	Lengt
·001	1·00002	**·009**	1·00022	**·017**	1·00078	**·025**	1·0016
·002	1·00002	**·010**	1·00027	**·018**	1·00081	**·026**	1·0018
·003	1·00003	**·011**	1·00032	**·019**	1·00097	**·027**	1·0019
·004	1·00004	**·012**	1·00038	**·020**	1·00107	**·028**	1·0021
·005	1·00007	**·013**	1·00045	**·021**	1·00117	**·029**	1·0022
·006	1·00010	**·014**	1·00053	**·022**	1·00128	**·030**	1·0024
·007	1·00013	**·015**	1·00061	**·023**	1·00140	**·031**	1·0025
·008	1·00017	**·016**	1·00069	**·024**	1·00153	**·032**	1·0027

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* See Introduction, *ante*, p. 7.

Height.	Length.	Height.	Length.	Height.	Length.	Height.	Length.
·033	1·00289	**·076**	1·01533	**·119**	1·03734	**·162**	1·06858
·034	1·00307	**·077**	1·01573	**·120**	1·03797	**·163**	1·06941
·035	1·00327	**·078**	1·01614	**·121**	1·03860	**·164**	1·07025
·036	1·00345	**·079**	1·01656	**·122**	1·03923	**·165**	1·07109
·037	1·00364	**·080**	1·01698	**·123**	1·03987	**·166**	1·07194
·038	1·00384	**·081**	1·01741	**·124**	1·04051	**·167**	1·07279
·039	1·00405	**·082**	1·01784	**·125**	1·04116	**·168**	1·07365
·040	1·00426	**·083**	1·01828	**·126**	1·04181	**.169**	1·07451
·041	1·00447	**·084**	1·01872	**·127**	1·04247	**·170**	1·07537
·042	1·00469	**·085**	1·01916	**·128**	1·04313	**·171**	1·07624
·043	1·00492	**·086**	1·01961	**·129**	1·04380	**·172**	1·07711
·044	1·00515	**·087**	1·02006	**·130**	1·04447	**·173**	1·07799
·045	1·00539	**·088**	1·02052	**·131**	1·04515	**·174**	1·07888
·046	1·00563	**·089**	1·02098	**·132**	1·04584	**·175**	1·07977
·047	1·00587	**·090**	1·02146	**·133**	1·04652	**·176**	1·08066
·048	1·00612	**·091**	1·02192	**·134**	1·04722	**·177**	1·08156
·049	1·00638	**·092**	1·02240	**·135**	1·04792	**·178**	1·08246
·050	1·00665	**·093**	1·02289	**·136**	1·04862	**·179**	1·08337
·051	1·00692	**·094**	1·02339	**·137**	1·04932	**·180**	1·08428
·052	1·00720	**·095**	1·02389	**·138**	1·05003	**·181**	1·08519
·053	1·00748	**·096**	1·02440	**·139**	1·05075	**·182**	1·08611
·054	1·00776	**·097**	1·02491	**·140**	1·05147	**·183**	1·08704
·055	1·00805	**·098**	1·02542	**·141**	1·05220	**·184**	1·08797
·056	1·00834	**·099**	1·02593	**·142**	1·05293	**·185**	1·08890
·057	1·00864	**·100**	1·02646	**·143**	1·05367	**·186**	1·08984
·058	1·00895	**·101**	1·02698	**·144**	1·05441	**·187**	1·09079
·059	1·00926	**·102**	1·02752	**·145**	1·05516	**·188**	1·09174
·060	1·00957	**·103**	1·02806	**·146**	1·05591	**·189**	1·09269
·061	1·00989	**·104**	1·02860	**·147**	1·05667	**·190**	1·09365
·062	1·01021	**·105**	1·02914	**·148**	1·05743	**·191**	1·09461
·063	1·01054	**·106**	1·02970	**·149**	1·05819	**·192**	1·09557
·064	1·01088	**·107**	1·03026	**·150**	1·05896	**·193**	1·09654
·065	1·01123	**·108**	1·03082	**·151**	1·05973	**·194**	1·09752
·066	1·01158	**·109**	1·03139	**·152**	1·06051	**·195**	1·09850
·067	1·01193	**·110**	1·03196	**·153**	1·06130	**·196**	1·09949
·068	1·01229	**·111**	1·03254	**·154**	1·06209	**·197**	1·10048
·069	1·01264	**·112**	1·03312	**·155**	1·06288	**·198**	1·10147
·070	1·01302	**·113**	1·03371	**·156**	1·06368	**·199**	1·10247
·071	1·01338	**·114**	1·03430	**·157**	1·06449	**·200**	1·10347
·072	1·01376	**·115**	1·03490	**·158**	1·06530	**·201**	1·10447
·073	1·01414	**·116**	1·03551	**·159**	1·06611	**·202**	1·10548
·074	1·01453	**·117**	1·03611	**·160**	1·06693	**·203**	1·10650
·075	1·01493	**·118**	1·03672	**·161**	1·06775	**·204**	1·10752

Height.	Length.	Height.	Length.	Height.	Length.	Height.	Length.
·205	1·10855	**·248**	1·15670	**·291**	1·21239	**·334**	1·27502
·206	1·10958	**·249**	1·15791	**·292**	1·21377	**·335**	1·27656
·207	1·11062	**·250**	1·15912	**·293**	1·21515	**·336**	1·27810
·208	1·11165	**·251**	1·16034	**·294**	1·21654	**·337**	1·27864
·209	1·11269	**·252**	1·16156	**·295**	1·21794	**·338**	1·28118
·210	1·11374	**·253**	1·16279	**·296**	1·21933	**·339**	1·28273
·211	1·11479	**·254**	1·16402	**·297**	1·22073	**·340**	1·28428
·212	1·11584	**·255**	1·16526	**·298**	1·22213	**·341**	1·28583
·213	1·11690	**·256**	1·16650	**·299**	1·22354	**·342**	1·28739
·214	1·11796	**·257**	1·16774	**·300**	1·22495	**·343**	1·28895
·215	1·11904	**·258**	1·16899	**·301**	1·22636	**·344**	1·29052
·216	1·12011	**·259**	1·17024	**·302**	1·22778	**·345**	1·29209
·217	1·12118	**·260**	1·17150	**·308**	1·22920	**·346**	1·29366
·218	1·12225	**·261**	1·17276	**·304**	1·23063	**·347**	1·29523
·219	1·12334	**·262**	1·17403	**·305**	1·23206	**·348**	1·29681
·220	1·12444	**·263**	1·17530	**·306**	1·23349	**·349**	1·29838
·221	1·12554	**·264**	1·17657	**·307**	1·23492	**·350**	1·29997
·222	1·12664	**·265**	1·17784	**·308**	1·23636	**·351**	1·30156
·223	1·12774	**·266**	1·17912	**·309**	1·23780	**·352**	1·30315
·224	1·12885	**·267**	1·18040	**·310**	1·23926	**·353**	1·30474
·225	1·12997	**·268**	1·18169	**·311**	1·24070	**·354**	1·30634
·226	1·13108	**·269**	1·18299	**·312**	1·24216	**·355**	1·30794
·227	1·13219	**·270**	1·18429	**·313**	1·24361	**·356**	1·30954
·228	1·13331	**·271**	1·18559	**·314**	1·24507	**·357**	1·31115
·229	1·13444	**·272**	1·18689	**·315**	1·24654	**·358**	1·31276
·230	1·13557	**·273**	1·18820	**·316**	1·24801	**·359**	1·31437
·231	1·13671	**·274**	1·18951	**·317**	1·24948	**·360**	1·31599
·232	1·13785	**·275**	1·19082	**·318**	1·25095	**·361**	1·31761
·233	1·13900	**·276**	1·19214	**·319**	1·25243	**·362**	1·31923
·234	1·14015	**·277**	1·19346	**·320**	1·25391	**·363**	1·32086
·235	1·14131	**·278**	1·19479	**·321**	1·25540	**·364**	1·32249
·236	1·14247	**·279**	1·19612	**·322**	1·25689	**·365**	1·32413
·237	1·14363	**·280**	1·19746	**·323**	1·25838	**·366**	1·32577
·238	1·14480	**·281**	1·19880	**·324**	1·25988	**·367**	1·32741
·239	1·14597	**·282**	1·20014	**·325**	1·26138	**·368**	1·32905
·240	1·14714	**·283**	1·20149	**·326**	1·26288	**·339**	1·33069
·241	1·14832	**·284**	1·20284	**·327**	1·26437	**·370**	1·33234
·242	1·14951	**·285**	1·20419	**·328**	1·26588	**·371**	1·33399
·243	1·15070	**·286**	1·20555	**·329**	1·26740	**·372**	1·33564
·244	1·15189	**·287**	1·20691	**·330**	1·26892	**·373**	1·33730
·245	1·15308	**·288**	1·20827	**·331**	1·27044	**·374**	1·33896
·246	1·15428	**·289**	1·20964	**·332**	1·27196	**·375**	1·34063
·247	1·15549	**·290**	1·21202	**·333**	1·27349	**·376**	1·34229

Height.	Length.	Height.	Length.	Height.	Length.	Height.	Length.
·377	1·34396	·408	1·39724	·439	1·45327	·470	1·51185
·378	1·34563	·409	1·39900	·440	1·45512	·471	1·51378
·379	1·34731	·410	1·40077	·441	1·45697	·472	1·51571
·380	1·34899	·411	1·40254	·442	1·45883	·473	1·51764
·381	1·35068	·412	1·40432	·443	1·46069	·474	1·51958
·382	1·35237	·413	1·40610	·444	1·46255	·475	1·52152
·383	1·35406	·414	1·40788	·445	1·46441	·476	1·52346
·384	1·35575	·415	1·40966	·446	1·46628	·477	1·52541
·385	1·35744	·416	1·41145	·447	1·46815	·478	1·52736
·386	1·35914	·417	1·41324	·448	1·47002	·479	1·52931
·387	1·36084	·418	1·41503	·449	1·47189	·480	1·53126
·388	1·36254	·419	1·41682	·450	1·47377	·481	1·53322
·389	1·36425	·420	1·41861	·451	1·47565	·482	1·53518
·390	1·36596	·421	1·42041	·452	1·47753	·483	1·53714
·391	1·36767	·422	1·42221	·453	1·47942	·484	1·53910
·392	1·36939	·423	1·42402	·454	1·48131	·485	1·54106
·393	1·37111	·424	1·42583	·455	1·48320	·486	1·54302
·394	1·37283	·425	1·42764	·456	1·48509	·487	1·54499
·395	1·37455	·426	1·42945	·457	1·48699	·488	1·54696
·396	1·37628	·427	1·43127	·458	1·48889	·489	1·54893
·397	1·37801	·428	1·43309	·459	1·49079	·490	1·55091
·398	1·37974	·429	1·43491	·460	1·49269	·491	1·55289
·399	1·38148	·430	1·43673	·461	1·49460	·492	1·55487
·400	1·38322	·431	1·43856	·462	1·49651	·493	1·55685
·401	1·38496	·432	1·44039	·463	1·49842	·494	1·55854
·402	1·38671	·433	1·44222	·464	1·50033	·495	1·56083
·403	1·38846	·434	1·44405	·465	1·50224	·496	1·56282
·404	1·39021	·435	1·44589	·466	1·50416	·497	1·56481
·405	1·39196	·436	1·44773	·467	1·50608	·498	1·56681
·406	1·39372	·437	1·44957	·468	1·50800	·499	1·56881
·407	1·39548	·438	1·45142	·469	1·50992	·500	1·57080

TABLE 10.—AREAS OF CIRCULAR SEGMENTS, UP TO A SEMICIRCLE.*

(DIAMETER OF CIRCLE = 1.)

Height.	Area.	Height.	Area.	Height.	Area.	Height.	Area.
·001	·000042	·005	·000471	·009	·001135	·013	·00197
·002	·000119	·006	·000619	·010	·00133	·014	·00220
·003	·000219	·007	·000779	·011	·00153	·015	·00244
·004	·000337	·008	·000952	·012	·00175	·016	·00268

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* See Introduction, *ante*, p. 7.

Height.	Area.	Height.	Area.	Height.	Area.	Height.	Area.
·017	·00294	**·060**	·01924	**·103**	·04269	**·146**	·07103
·018	·00320	**·061**	·01972	**·104**	·04330	**·147**	·07174
·019	·00347	**·062**	·02020	**·105**	·04391	**·148**	·07245
·020	·00375	**·063**	·02068	**·106**	·04452	**·149**	·07316
·021	·00403	**·064**	·02117	**·107**	·04514	**·150**	·07387
·022	·00432	**·065**	·02166	**·108**	·04576	**·151**	·07459
·023	·00461	**·066**	·02215	**·109**	·04638	**·152**	·07530
·024	·00492	**·067**	·02265	**·110**	·04701	**·153**	·07603
·025	·00523	**·068**	·02315	**·111**	·04763	**·154**	·07675
·026	·00555	**·069**	·02366	**·112**	·04826	**·155**	·07747
·027	·00587	**·070**	·02417	**·113**	·04889	**·156**	·07819
·028	·00619	**·071**	·02468	**·114**	·04953	**·157**	·07892
·029	·00653	**·072**	·02520	**·115**	·05016	**·158**	·07965
·030	·00687	**·073**	·02571	**·116**	·05080	**·159**	·08038
·031	·00721	**·074**	·02624	**·117**	·05145	**·160**	·08111
·032	·00756	**·075**	·02676	**·118**	·05209	**·161**	·08185
·033	·00792	**·076**	·02729	**·119**	·05274	**·162**	·08258
·034	·00828	**·077**	·02782	**·120**	·05338	**·163**	·08332
·035	·00864	**·078**	·02836	**·121**	·05404	**·164**	·08406
·036	·00901	**·079**	·02889	**·122**	·05469	**·165**	·08480
·037	·00939	**·080**	·02943	**·123**	·05535	**·166**	·08554
·038	·00977	**·081**	·02997	**·124**	·05600	**·167**	·08629
·039	·01015	**·082**	·03053	**·125**	·05666	**·168**	·08704
·040	·01054	**·083**	·03108	**·126**	·05733	**·169**	·08778
·041	·01093	**·084**	·03163	**·127**	·05799	**·170**	·08854
·042	·01133	**·085**	·03219	**·128**	·05866	**·171**	·08929
·043	·01173	**·086**	·03275	**·129**	·05933	**·172**	·09004
·044	·01214	**·087**	·03331	**·130**	·06000	**·173**	·09080
·045	·01255	**·088**	·03385	**·131**	·06067	**·174**	·09155
·046	·01297	**·089**	·03444	**·132**	·06135	**·175**	·09231
·047	·01340	**·090**	·03501	**·133**	·06203	**·176**	·09307
·048	·01382	**·091**	·03538	**·134**	·06271	**·177**	·09383
·049	·01425	**·092**	·03616	**·135**	·06339	**·178**	·09460
·050	·01468	**·093**	·03674	**·136**	·06407	**·179**	·09537
·051	·01512	**·094**	·03732	**·137**	·06476	**·180**	·09613
·052	·01556	**·095**	·03790	**·138**	·06545	**·181**	·09690
·053	·01601	**·096**	·03850	**·139**	·06614	**·182**	·09767
·054	·01646	**·097**	·03909	**·140**	·06683	**·183**	·09845
·055	·01691	**·098**	·03968	**·141**	·06753	**·184**	·09922
·056	·01737	**·099**	·04028	**·142**	·06822	**·185**	·09999
·057	·01783	**·100**	·04087	**·143**	·06892	**·186**	·10077
·058	·01830	**·101**	·04148	**·144**	·06963	**·187**	·10153
·059	·01877	**·102**	·04208	**·145**	·07033	**·188**	·10233

Height.	Area.	Height.	Area.	Height.	Area.	Height.	Area.
·189	·10317	**·232**	·13815	**·275**	·17554	**·318**	·21480
·190	·10390	**·233**	·13899	**·276**	·17644	**·319**	·21573
·191	·10469	**·234**	·13984	**·277**	·17733	**·320**	·21667
·192	·10547	**·235**	·14069	**·278**	·17823	**·321**	·21760
·193	·10626	**·236**	·14154	**·279**	·17912	**·322**	·21853
·194	·10705	**·237**	·14239	**·280**	·18002	**·323**	·21947
·195	·10784	**·238**	·14324	**·281**	·18092	**·324**	·22040
·196	·10864	**·239**	·14409	**·282**	·18182	**·325**	·22134
·197	·10943	**·240**	·14494	**·283**	·18272	**·326**	·22228
·198	·11023	**·241**	·14580	**·284**	·18362	**·327**	·22322
·199	·11102	**·242**	·14665	**·285**	·18452	**·328**	·22415
·200	·11182	**·243**	·14752	**·286**	·18542	**·329**	·22509
·201	·11262	**·244**	·14837	**·287**	·18633	**·330**	·22603
·202	·11343	**·245**	·14923	**·288**	·18723	**·331**	·22697
·203	·11423	**·246**	·15009	**·289**	·18814	**·332**	·22792
·204	·11504	**·247**	·15096	**·290**	·18905	**·333**	·22886
·205	·11584	**·248**	·15182	**·291**	·18996	**·334**	·22980
·206	·11665	**·249**	·15268	**·292**	·19086	**·335**	·23074
·207	·11746	**·250**	·15355	**·293**	·19177	**·336**	·23169
·208	·11827	**·251**	·15442	**·294**	·19268	**·337**	·23263
·209	·11908	**·252**	·15528	**·295**	·19360	**·338**	·23358
·210	·11990	**·253**	·15615	**·296**	·19451	**·339**	·23453
·211	·12071	**·254**	·15702	**·297**	·19543	**·340**	·23547
·212	·12153	**·255**	·15789	**·298**	·19634	**·341**	·23642
·213	·12235	**·256**	·15876	**·299**	·19725	**·342**	·23737
·214	·12317	**·257**	·15964	**·300**	·19817	**·343**	·23832
·215	·12399	**·258**	·16051	**·301**	·19908	**·344**	·23927
·216	·12481	**·259**	·16139	**·302**	·20000	**·345**	·24025
·217	·12563	**·260**	·16226	**·303**	·20092	**·346**	·24117
·218	·12646	**·261**	·16314	**·304**	·20184	**·347**	·24212
·219	·12729	**·262**	·16402	**·305**	·20276	**·348**	·24307
·220	·12811	**·263**	·16490	**·306**	·20368	**·349**	·24403
·221	·12894	**·264**	·16578	**·307**	·20460	**·350**	·24498
·222	·12977	**·265**	·16666	**·308**	·20553	**·351**	·24593
·223	·13060	**·266**	·16755	**·309**	·20645	**·352**	·24689
·224	·13144	**·267**	·16843	**·310**	·20738	**.353**	·24784
·225	·13227	**·268**	·16932	**·311**	·20830	**·354**	·24880
·226	·13311	**·269**	·17020	**·312**	·20923	**·355**	·24976
·227	·13395	**·270**	·17109	**·313**	·21015	**·356**	·25071
·228	·13478	**·271**	·17198	**·314**	·21108	**·357**	·25167
·229	·13562	**·272**	·17287	**·315**	·21201	**·358**	·25263
·230	·13646	**·273**	·17376	**·316**	·21294	**·359**	·25359
·231	·13731	**·274**	·17465	**·317**	·21387	**·360**	·25455

Height.	Area.	Height.	Area.	Height.	Area.	Height.	Area.
·361	·25551	·391	·28457	·421	·31403	·451	·34378
·362	·25647	·392	·28554	·422	·31502	·453	·34577
·363	·25743	·393	·28652	·423	·31600	·455	·34776
·364	·25839	·394	·28750	·424	·31699	·457	·34975
·365	·25936	·395	·28848	·425	·31798	·459	·35174
·366	·26032	·396	·28955	·426	·31897	·462	·35474
·367	·26128	·397	·29043	·427	·31996	·464	·35673
·368	·26225	·398	·29141	·428	·32095	·466	·35873
·369	·26321	·399	·29239	·429	·32194	·468	·36072
·370	·26418	·400	·29337	·430	·32293	·470	·36272
·371	·26514	·401	·29435	·431	·32392	·471	·36371
·372	·26611	·402	·29533	·432	·32491	·473	·36571
·373	·26708	·403	·29631	·433	·32590	·475	·36771
·374	·26805	·404	·29729	·434	·32689	·477	·36971
·375	·26901	·405	·29827	·435	·32788	·479	·37170
·376	·26998	·406	·29926	·436	·32887	·482	·37470
·377	·27095	·407	·30024	·437	·32987	·484	·37670
·378	·27192	·408	·30122	·438	·33086	·486	·37870
·379	·27289	·409	·30220	·439	·33185	·488	·38070
·380	·27386	·410	·30319	·440	·33284	·490	·38270
·381	·27483	·411	·30417	·441	·33384	·491	·38370
·382	·27580	·412	·30516	·442	·33483	·492	·38470
·383	·27678	·413	·30614	·443	·33582	·493	·38570
·384	·27775	·414	·30712	·444	·33682	·494	·38670
·385	·27872	·415	·30811	·445	·33781	·495	·38770
·386	·27969	·416	·30910	·446	·33880	·496	·38870
·387	·28070	·417	·31008	·447	·33980	·497	·38970
·388	·28164	·418	·31107	·448	·34079	·498	·39070
·389	·28262	·419	·31205	·449	·34179	·499	·39170
·390	·28359	·420	·31304	·450	·34278	·500	·39270

TABLE 11.—LENGTHS OF SEMI-ELLIPTIC ARCS.

(J. C. Trautwine.)*

(SPAN = 1).

Height.	Length.	Height.	Length.	Height.	Length.	Height.	Length.
·02	1·003	·045	1·014	·07	1·029	·095	1·046
·025	1·004	·05	1·017	·075	1·032	·100	1·051
·03	1·006	·055	1·020	·08	1·036	·105	1·055
·035	1·008	·06	1·023	·085	1·039	·110	1·059
·04	1·011	·065	1·026	·09	1·043	·115	1·064

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* See Introduction, *ante*, p. 7.

Height.	Length.	Height.	Length.	Height.	Length.	Height.	Length.
·120	1·069	·220	1·177	·315	1·298	·410	1·434
·125	1·074	·225	1·183	·320	1·305	·415	1·441
·130	1·079	·230	1·189	·325	1·312	·420	1·449
·135	1·084	·235	1·196	·330	1·319	·425	1·456
·140	1·089	·240	1·202	·335	1·325	·430	1·464
·145	1·094	·245	1·207	·340	1·332	·435	1·471
·150	1·099	·250	1·213	·345	1·339	·440	1·479
·155	1·104	·255	1·219	·350	1·346	·445	1·486
·160	1·109	·260	1·226	·355	1·353	·450	1·494
·165	1·115	·265	1·233	·360	1·361	·455	1·501
·170	1·120	·270	1·239	·365	1·368	·460	1·509
·175	1·125	·275	1·245	·370	1·375	·465	1·517
·180	1·131	·280	1·252	·375	1·382	·470	1·524
·185	1·137	·285	1·259	·380	1·390	·475	1·532
·190	1·142	·290	1·265	·385	1·397	·480	1·540
·195	1·147	·295	1·272	·390	1·404	·485	1·547
·200	1·153	·300	1·279	·395	1·412	·490	1·555
·205	1·159	·305	1·285	·400	1·419	·495	1·563
·210	1·165	·310	1·292	·405	1·426	·500	1·571
·215	1·171						

MEASUREMENT OF SURFACES AND SOLIDS.

Plane Surfaces.

The area of a triangle is equal to half the product of the base by the perpendicular height.

The area of a parallelogram is equal to the product of the length by the height.

The area of a trapezoid (a parallel-sided figure of four sides, having two sides not parallel) is equal to the product of half the sum of the parallel sides by the distance between them.

The area of any quadrilateral or *four-sided figure*, is found by dividing the figure into two triangles; the sum of the areas of which is the area of the quadrilateral.

The area of a square or a *rhombus* (an oblique-angled equal-sided parallelogram) is equal to half the product of the diagonals.

The area of a polygon or *many-sided figure* is found by dividing the figure into triangles and trapezoids; the sum of the areas of these is the area of the figure.

The area of a regular polygon is half the product found by multiplying the length of the side by the number of sides and by the perpendicular from the centre to one of the sides. In Table 12, columns 3 and 4 respectively are the lengths of the perpendiculars and the areas of the figures, when the length of the side is equal to 1; also the areas of polygons having an even number of sides, when the width across, between parallel sides (or twice the perpendicular length), is equal to 1. A line is added to the table showing the relation of the circle as a polygon having an indefinitely great number of sides.

TABLE 12.—REGULAR POLYGONS.

Designation of Polygon. 1.	Number of Sides. 2.	Perpendicular. (Side = 1.) 3.	Area. (Side = 1.) 4.	Area. (Width across = 1.) 5.
Equilateral triangle.	3	0·2887	0·4330	...
Square . . .	4	0·5000	1·0000	1·0000
Pentagon . . .	5	0·6882	1·7205	...
Hexagon . . .	6	0·8660	2·5981	0·8661
Heptagon . . .	7	1·0383	3·6339	...
Octagon . . .	8	1·2071	4·8284	0·3284
Nonagon . . .	9	1·3737	6·1818	...
Decagon . . .	10	1·5388	7·6942	0·8123
Undecagon . . .	11	1·7028	9·3656	...
Dodecagon . . .	12	1·8660	11·1962	0·8082
Circle . . .	infinite	infinite	infinite	0·7854

When the length of the side is other than 1, the perpendiculars and areas are to be calculated by squaring the given value of the side and multiplying the square by the corresponding coefficient in the table: column 3 for the perpendicular, column 4 for the area.

When the width across is other than 1, the area is to be calculated by squaring the value of the given width and multiplying the square by the corresponding coefficient in column 5.

A Regular Polygon may be inscribed in a circle. To supply a means of dividing the circumference of a circle into any number of equal parts, with a view to inscription of a polygon, the annexed tablet of angles at the centre subtended by the sides of polygons, expressed in degrees, is of general utility. Set off round the centre of the circle a succession of angles by means of the protractor, equal to the angle in the table due to a given number of sides. The radii so drawn divide the cir cumference into the same number of parts. The triangles thus formed are the elementary triangles of the polygon.

TABLE 13.—POLYGONAL ANGLES AT THE CENTRE.

Number of Sides of Polygon.	Elementary Angle at Centre.	Number of Sides of Polygon.	Elementary Angle at Centre.
Sides.	Degrees.	Sides.	Degrees.
3	120	12	30
4	90	13	$27\frac{9}{13}$
5	72	14	$25\frac{5}{7}$
6	60	15	24
7	$51\frac{3}{7}$	16	$22\frac{1}{2}$
8	45	17	$21\frac{3}{17}$
9	40	18	20
10	36	19	19 (exactly $18\frac{18}{19}$)
11	$32\frac{8}{11}$	20	18

Circle.

The circumference of a circle is 3·1416 times the diameter; or, approximately, $3\frac{1}{7}$ times. Or, the diameter is to the circumference as 7 to 22, approximately; or as 113 to 355. Trigonometrically, the circle is divisible into 360 degrees.

When the *diameter* is 1, the area is equal to ·7854, or approximately 4-5ths. The area of a circle of a given diameter is found by multiplying the square of the diameter by ·7854.

The length of an arc of a circle is found by multiplying the number of degrees in the arc by the radius, and by ·01745. Or, approximately, by subtracting the chord of the arc from eight times the chord of half the arc; and taking one-third of the remainder.

The area of a sector of a circle is equal to the product of half the length of the arc of the sector by the radius. Or, multiply the number of degrees in the arc by the square of the radius, and by ·008727.

The area of a segment of a circle. Find the area of the sector which has the same arc as the segment; also the area of the triangle formed by the radial sides of the sector and the chord of the arc. The difference or the sum of these areas is the area of the segment, according as it is less or greater than a semicircle.

The area of a ring. Multiply the sum of the outer and inner diameters by their difference and by ·7854.

The area of a zone of a circle. Find the areas of the two segments cut off, and subtract the sum of these areas from the area of the whole circle, to give the area of the zone.

The side of a square equal in area to a given circle is equal to the product of the diameter by ·8862.

The side of a square inscribed in a circle is equal to the product of the diameter by ·7071.

The area of an inscribed square is equal to the product of the area of the circle by ·6366.

The diameter of a circle equal in area to a given square is equal to the product of the side of the square by 1·1284, or $1\frac{1}{8}$ approximately.

The diameter of a circumscribing circle is equal to the product of the side of the given square by 1·4142.

The area of a circumscribing circle is equal to the product of the area of the given square by 1·5708.

Ellipse.

The circumference of an ellipse is equal to the product of the square root of half the sum of the squares of the two axes by 3·1416.

This rule is approximate. Mr. Trautwine proposes the following formula for the circumference of an ellipse, as more nearly exact, and sufficiently so for ordinary purposes. When the longer axis, D, is not more than five times the length of the shorter axis, d,

$$\text{Circumference} = 3{\cdot}1416\sqrt{\frac{D^2 + d^2}{2} - \frac{(D - d)^2}{8{\cdot}8}} \quad . \quad (1)$$

When the longer axis is more than five lengths of the shorter axis, the divisor 8·8 under the sign is to be replaced by the following divisors :—

	Divisor.
When the longer axis is 6 times the shorter	9
” ” 7 ” ”	9·2
” ” 8 ” ”	9·3
” ” 9 ” ”	9·35
” ” 10 ” ”	9·4
” ” 12 ” ”	9·5
” ” 14 ” ”	9·6
” ” 16 ” ”	9·68
” ” 18 ” ”	9·75
” ” 20 ” ”	9·8
” ” 25 ” ”	9·87
” ” 30 ” ”	9·92
” ” 40 ” ”	9·98
” ” 50 ” ”	10·00

The area of an ellipse is equal to the product of the two axes by ·7854.

The area of a segment of an ellipse, the base of which is parallel to one of the axes of the ellipse. Divide the height of the segment by the axis of which it is a part, and find the area of a circular segment, in a table of circular segments, of which the height is equal to the quotient; multiply the area thus found by the two axes of the ellipse successively; the product is the area.

Curvilineal Figures.

The area of any curvilineal figure bounded at the ends by parallel straight lines by Simpson's rule. Divide the length of the figure into any even number of equal parts, at the common distance D apart, and draw ordinates through the points of division, to touch the boundary lines. Add together the first and last ordinates, and call the sum A; add together the even ordinates, and call the sum B; add together the odd ordinates, except the first and last, and call the sum C. Then,

$$\text{area of the figure} = \frac{A + 4\,B + 2\,C}{3} \times D \quad . \quad (2)$$

2nd Method.—Divide the figure into any sufficient number, n, of equal parts; add together the first and last ordinates, making the sum A; add together all the intermediate ordinates, making the sum B. Putting L for the length of the figure. Then,

$$\text{area of the figure} = \frac{A + 2\,B}{2\,n} \times L \quad . \quad . \quad (3)$$

3rd Method.—Divide the figure into a sufficient number of equal parts, as before. Add together the mean depths of the several divisions, and divide the sum by the number of divisions, to give the average depth; multiply the average depth by the total length, to give the area.

The figure may, otherwise, be divided into two half-parts, one at each end, and a number of whole parts intermediately. The sum of the ordinates, excepting the extreme ordinates, divided by the number of them, gives the average depth, and the product of this by the length, gives the area.

The figures may be bounded at the ends by curves or angles. In this case, the extreme ordinates become nothing.

Solids.

There are five species of regular solids, bounded by regular polygons, of which particulars are given in the annexed table:—

TABLE 14.—REGULAR SOLIDS.

Designation of Solid. 1	Number and Designation of Sides. 2	Superficial Area (Edge = 1) 3	Contents (Edge = 1) 4
Tetrahedron .	4 equilateral triangles .	1·7320	0·1178
Hexahedron, or Cube	6 squares . . .	6·0000	1·0000
Octahedron .	8 equilateral triangles .	3·4641	0·4714
Dodecahedron	12 pentagons . . .	20·6458	7·6631
Icosahedron .	20 equilateral triangles .	8·6603	2·1817

Regular solids may be circumscribed by spheres; and spheres may be inscribed in regular solids.

To find the total area of surface of a regular solid, multiply the square of the length of the edge by the tabular number given in column 3 of the table.

To find the contents of a regular solid, multiply the cube of the length of the edge by the tabular number in column 4 of the table.

The four leading solids are the cube, the cylinder, the sphere, and the cone. A cubic foot contains

1,728 cubic inches, or
2,200 cylindrical inches, or
3,300 spherical inches, or
6,600 conical inches.

These values supply an easy practical rule for finding, by proportion, the capacities of the "three round bodies."

The surface of a cylinder, or of a prism, is equal to the product of the perimeter of one end by the height; plus twice the area of one end.

The cubic content of a cylinder, or of a prism, is equal to the product of the area of the base by the length or height of the cylinder.

The surface of a sphere is equal to the product of the square of the diameter by 3·1416.

It is equal to four times the area of one of its great circles.

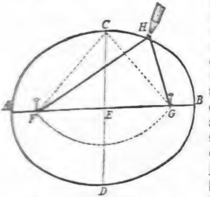
It is equal to the convex surface of its circumscribing cylinder.

The surfaces of spheres are to each other as the squares of their diameters.

The curve surface of a segment, or a zone of a sphere, is equal to the product of the diameter of the sphere by the height of the segment or zone, and by 3·1416. The curve

Note.—The second method is not exact, but it is sufficiently near to exactness for arcs less than one-fourth of a circle.

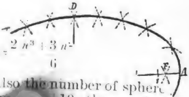
The Ellipse is a Curve such that the sum of the distances of any point in the curve from two fixed points or foci, is constant.



[illegible] an Ellipse.

To describe an Ellipse, when the length and width are given. On the centre C, fig. 3, with AE as radius, cut the axis AB at F and G, the foci. Fix a couple of pins into the axis a F and G, and loop thread or cord upon the equal in length to th axis AB, so as, whe stretched, to reach to th- extremity C of the con jugate axis. With pencil or draw-point i side the cord, as at guide the pencil in te sion about the pins F and G, and so describe the ellipse.

2nd Method. Bisect the transverse axis, fig. 4 at C, an through C draw the perpendicular DE, making CD and C each equal to half the conjugate axis. From D or E, with th



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$$S = \frac{2n^3 + 3n^2}{6}$$

The value *n* expresses also the number of sphere of the base. If, for exam =10, the number is, by the formula, (2,00 0)÷6 = 385.

2. *On a triangular*

$(n+2)$ . . (5)

n is equal to to 220.

3. *Oblong* *ctangular* uppermost ratum is *y m* in n

+1) (3 . . (6)

Sup h eq to 880.

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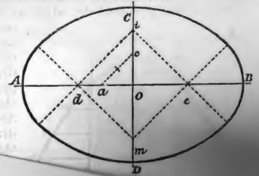
3rd Method (approximate). With arcs of two radii, fig. 5. Lay down the axes AB and CD, and set off O*a* and O*c* equal to the difference of the lengths of the axes. Draw *ac* and set off half of *ac* to *d*, and O*e* equal to O*d*. Draw *di*, *ei*, and parallels intersecting at *m*. From the centres *m* and *i*, describe arcs through C and D; … *d* and *e*, de- … A



…the an Ellipse.

…be described. …similarly, the re- … D, B, fig. 2, be the given points. …DB; and *cf* parallel to AB. Divide AD … of equal parts, at 1, 2, 3, &c., and from D

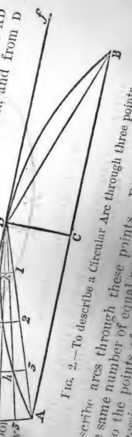


Fig. 2.—To describe a Circular Arc through three points.

describe arcs through these points. Divide the arc A*e* into the same number of equal parts, and draw straight lines from D to the points of division. The intersections of these lines successively with the arcs 1, 2, 3, &c., are points in the circle.

The surface of a frustum of a cone or a pyramid is equal to the product of the sum of the perimeters of the ends by half the slant height, plus the areas of the ends.

The content of a frustum of a cone or a pyramid is found by adding together the areas of the ends and the mean proportional between them (the square root of their product), and multiplying the sum by one-third of the perpendicular height.

Or, in the case of a conical frustum, add together the squares of the diameters and the product of the diameters and multiply the sum by ·7854, and by one-third of the height.

The content of a wedge is found by adding together twice the length of the base and the length of the edge, and multiplying the sum by the breadth of the base, and by one-sixth of the height.

The content of a prismoid (a solid having three or more inclined sides, and similar parallel ends) is found by adding together the areas of the ends, and four times the intermediate sectional area equally distant from the ends; and multiplying the sum by one-sixth of the length.

The content of an irregular solid may be found by dividing it into parts measurable by the ordinary rules, and adding together the contents of them; the sum is the content of the solid.

Piles of equal spheres or balls. Ranged usually in pyramidal piles, on a square or a triangular base; or in oblong piles on a rectangular base:—

1. *To find the number of balls in a pile on a square base.* Let n = the number of horizontal strata or layers of spheres in the piles, comprising the highest stratum, which consists of one sphere. The number, S, of spheres is

$$S=\frac{2\,n^3+3\,n^2+n}{6} \quad . \quad . \quad . \quad . \quad (4)$$

The value n expresses also the number of spheres in one side of the base. If, for example, $n=10$, the number of balls, S, is, by the formula, $(2{,}000+300+10)\div 6=385$.

2. *On a triangular base.*

$$S=\frac{n\,(n+1)\,(n+2)}{6} \quad . \quad . \quad . \quad . \quad (5)$$

If n is equal to 10, S is equal to 220.

3. *Oblong pile on a rectangular base.* The uppermost stratum is a row of balls, say m in number,

$$S=\frac{n\,(n+1)\,(3\,m+2\,n)-2}{6} \quad . \quad . \quad . \quad . \quad (6)$$

Supposing m and n each equal to 10, S is equal to 880.

DESCRIPTION OF CIRCULAR SEGMENTS, CONIC SECTIONS AND CYCLOIDS.

To describe a Circle passing through three given points, when the Centre is not available. From the extreme points A, B, fig. 1, as centres describe arcs AH, BG. Through the third point C draw AE, BF. Divide AF and BE into any convenient number of equal parts, and set off a series of equal parts of the same length on the upper portions of the arcs, beyond the points E, F. Draw straight lines BL, BM, &c., to the divisions in AF; and AI, AK, &c., to the division in EG. The successive intersections at N, O, &c., of these lines, are points in the circle required, between the given points A and C, which may be traced in accordingly. Similarly, the remaining part of the curve may be described.

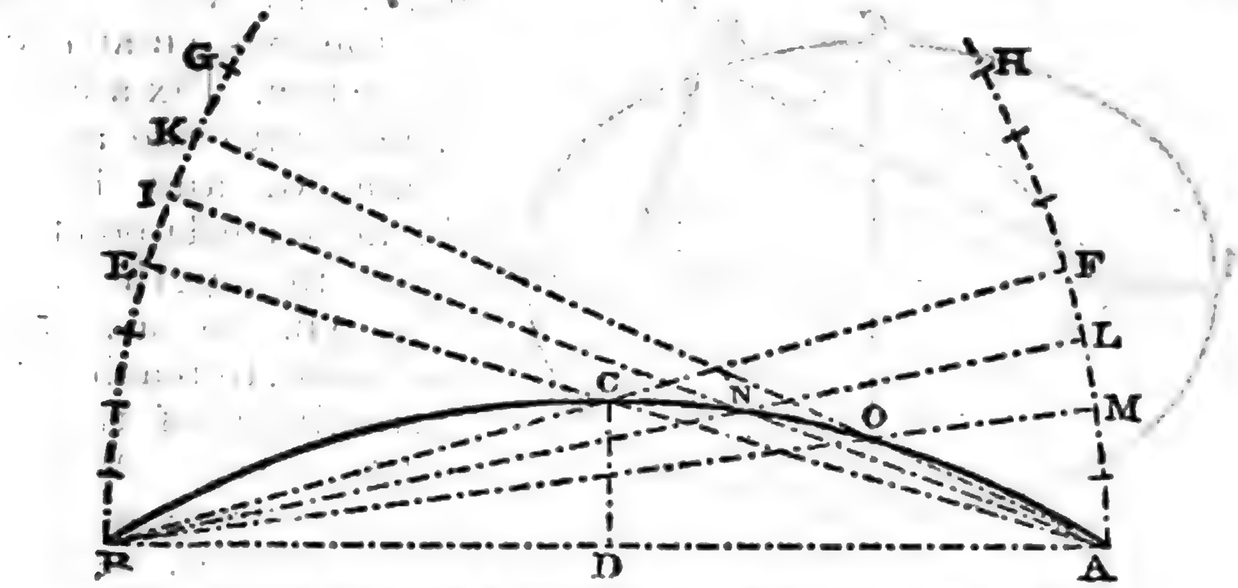


FIG. 1.—To describe a Circular Arc through three points.

2*nd Method.* Let A, D, B, fig. 2, be the given points. Draw AB, AD, and DB; and *ef* parallel to AB. Divide AD into a number of equal parts, at 1, 2, 3, &c., and from D

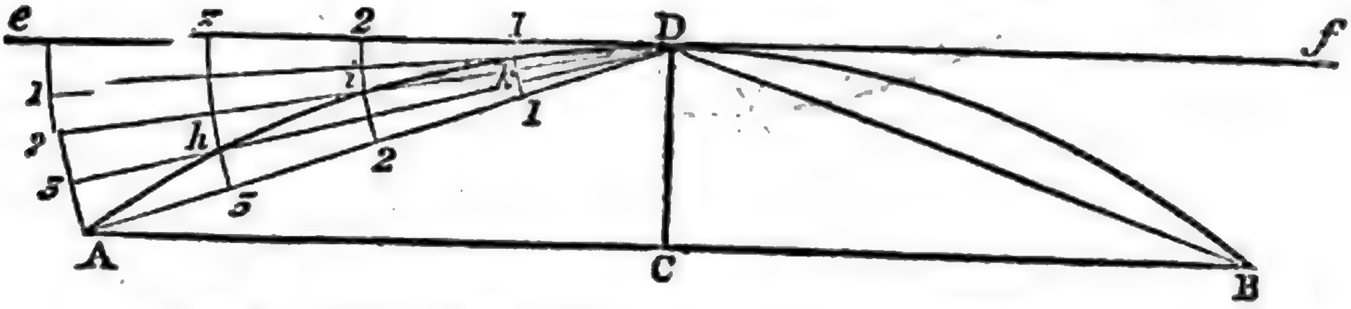


FIG. 2.—To describe a Circular Arc through three points.

describe arcs through these points. Divide the arc A*e* into the same number of equal parts, and draw straight lines from D to the points of division. The intersections of these li successively with the arcs 1, 2, 3, &c., are points in the c

Note.—The second method is not exact, but it is sufficiently near to exactness for arcs less than one-fourth of a circle.

The Ellipse is a Curve such that the sum of the distances of any point in the curve from two fixed points or foci, is constant.

To describe an Ellipse, when the length and width are given. On the centre C, fig. 3, with AE as radius, cut the axis AB at F and G, the foci. Fix a couple of pins into the axis at F and G, and loop a thread or cord upon them equal in length to the axis AB, so as, when stretched, to reach to the extremity C of the conjugate axis. With a pencil or draw-point inside the cord, as at H, guide the pencil in tension about the pins F and G, and so describe the ellipse.

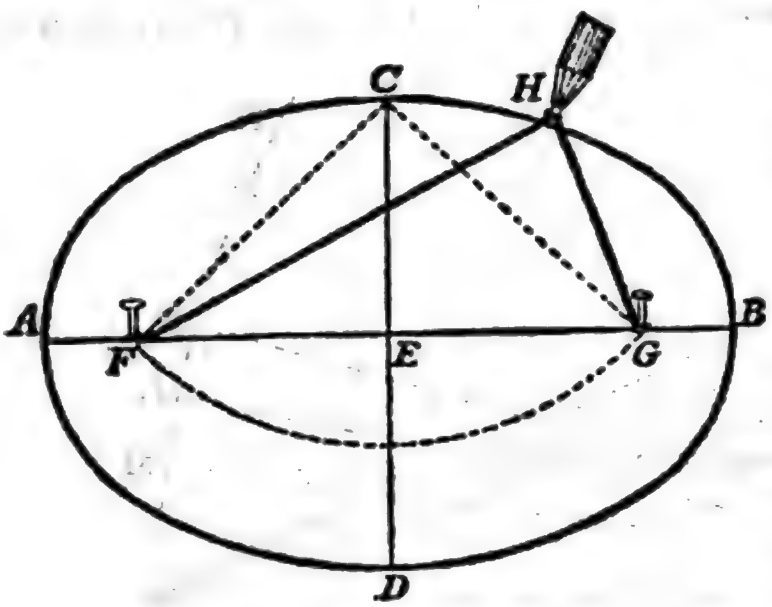


FIG. 3.—To describe an Ellipse.

2nd Method. Bisect the transverse axis, fig. 4 at C, and through C draw the perpendicular DE, making CD and CE each equal to half the conjugate axis. From D or E, with the radius AC cut the transverse axis at F, F′, for the foci. Divide AC into any number of parts at 1, 2, 3, &c. With the radius A1, on F and F′ as centres, describe arcs; and with the radius B1 on the same centres, cut these arcs, as shown. Repeat the operation for the other points of division of the transverse axis. The series of intersections thus made are points in the curve, through which the curve may be traced.

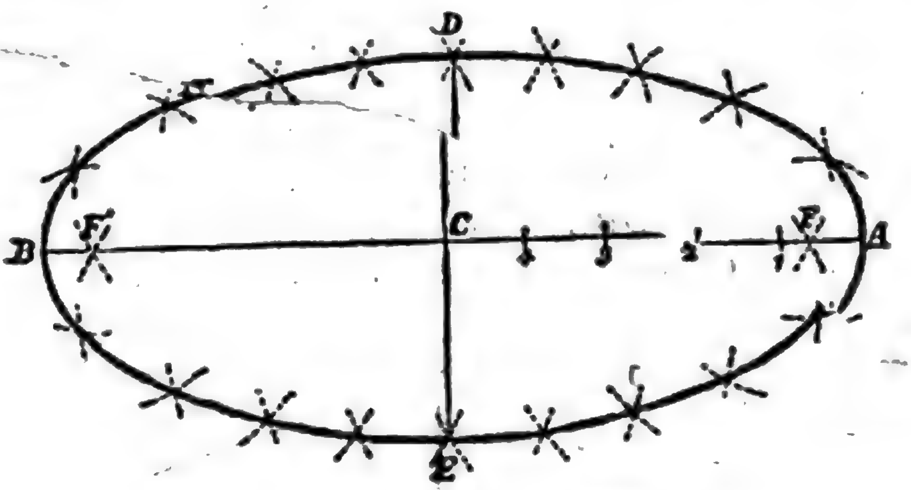


Fig. 4.—To describe an Ellipse.

3rd Method (approximate). With arcs of two radii, fig. 5. Lay down the axes AB and CD, and set off O*a* and O*c* equal to the difference of the lengths of the axes. Draw *ac* and set off half of *ac* to *d*, and O*e* equal to O*d*. Draw *di*, *ei*, and parallels intersecting at *m*. From the centres *m* and *i*, describe arcs through C and D; and from *d* and *e*, describe arcs through A and B. The four arcs form the ellipse.

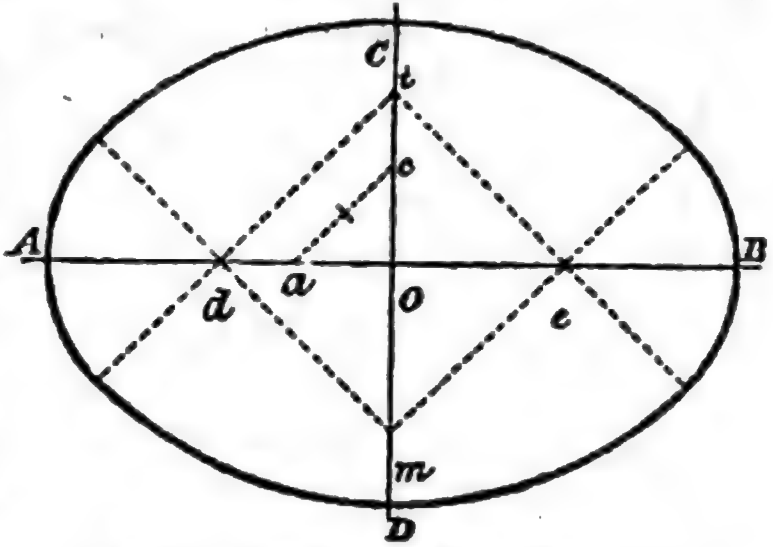


FIG. 5.—To describe an Ellipse.

Note. — This method is applicable when the conjugate axis is at least two-thirds of the transverse axis.

4th Method (approximate). With arcs of three radii, fig. 6.

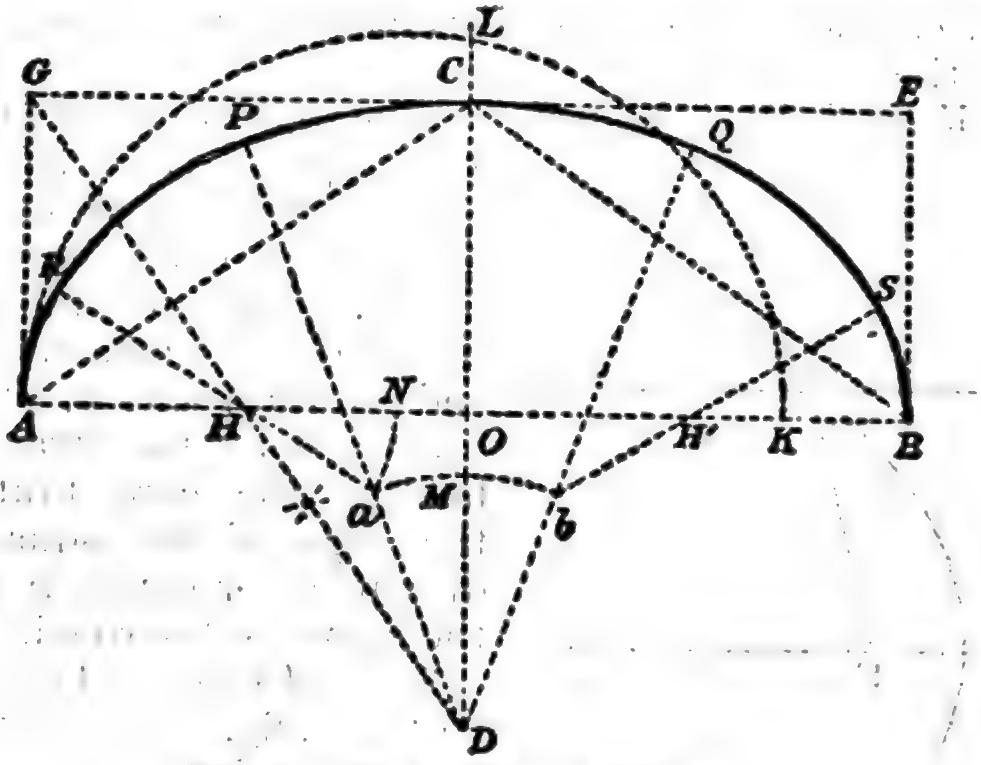


FIG. 6.—To describe an Ellipse.

On the transverse axis AB, draw the rectangle BG, on the height OC, of the semi-conjugate axis. To the diagonal AC draw the perpendicular GHD; set off OK equal to OC, and describe a semicircle on AK, and produce OC to L. Set off OM equal CL, and on D describe an arc with the radius DM. On A with radius OL, cut this arc at A. The five centres D, *a*, *b*, H, H', are found, from which the arcs are described to form the ellipse.

Note.—This process works well for nearly all proportions of ellipses.

The parabola is a curve such that the distance of any point in the curve from a fixed point, the focus, is equal to its distance from a straight line, the directrix.

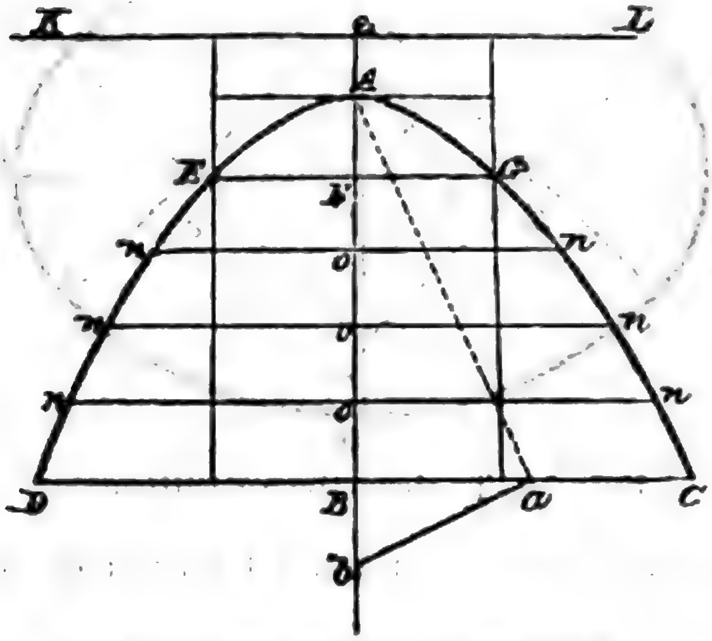


Fig. 7.—To describe a Parabola.

To describe a Parabola, when an absciss and its ordinate, or the height and the base, are given. Bisect the given ordinate BC, fig. 7, at *a*; draw A*a*, and then *ab* perpendicular to it, meeting the axis at *b*. Set off A*e*, AF, each equal to B*b*, and draw K*e*L at right angles to the axis. Then KL is the directrix and F is the focus. Through F and any number of points *o*, *o*, &c., in the axis, draw double ordinates *non*, &c., and on the centre F, with the radii FE, *oe*, &c., cut the respective ordinates at E, G, *n*, *n*, &c. The curve is traced through these points of intersection.

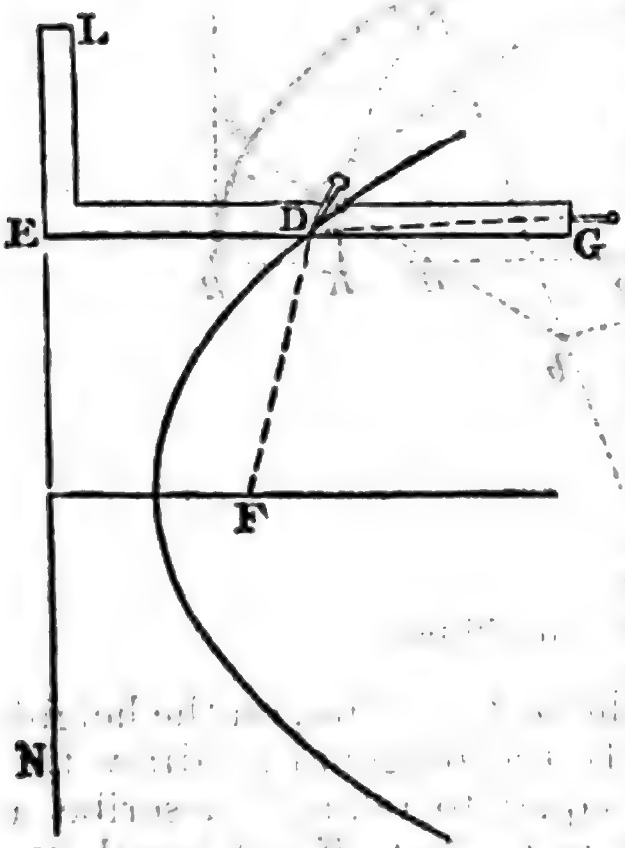


Fig. 8.—To describe a Parabola.

2nd Method. Place a straight-edge to the directrix EN, fig. 8, and apply to it a square LEG. Fasten to the end G one end of a thread or cord, shown in dot-lining, equal in length to the edge EG, and attach the other end to the focus F. Slide the square along the straight-edge, holding the cord taut against the edge of the square by a drawpoint or pencil D, by which the curve is described.

3rd Method. Through the vertex A, fig. 9, draw EF parallel to CD the base, and through C and D draw CE and DF parallel to the axis AB. Divide BC and BD into any number of equal parts, at *a*, *b*, &c., and divide CE and DF into the same number of equal parts. Through the points *a*, *b*, *c*, *d*, in the base CD, draw perpendiculars, and through *a*, *b*, *c*, *d* in CE and DF draw lines to the vertex A, cutting the perpendiculars at *e*, *f*, *g*, *h*. These are points in the curve, which may be traced through them.

The nature of the parabola is such that the abscissæ vary in length as the squares of the ordinates. Inversely, the ordinates vary as the square roots of the abscissæ. By means of these relations any number of points in the curve may be determined, and the curve constructed.

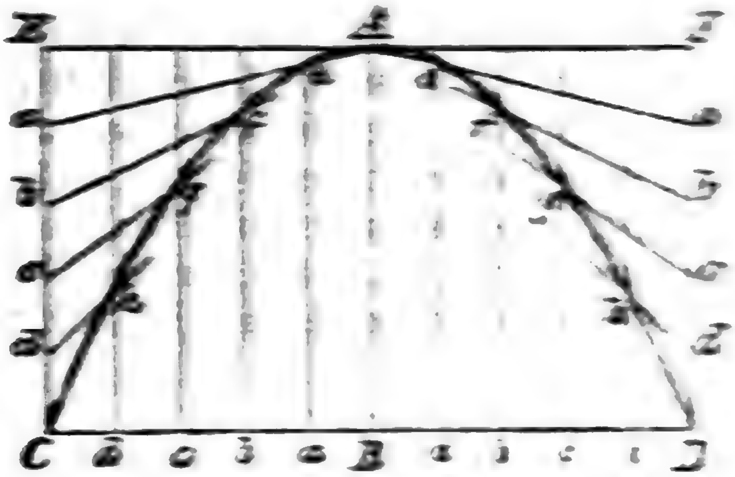


FIG. 9.—To describe a Parabola.

The hyperbola is a curve such that the difference of the distances of any point in the curve from two fixed points, the foci, is equal to a constant, the transverse axis. The vertices A, B, fig. 10, of opposite hyperbolas, are the heads of the curves, in their axial lines. The transverse axis AB is the distance between the vertices. The conjugate axis GH passes through the centre C, at right angles to the transverse axis.

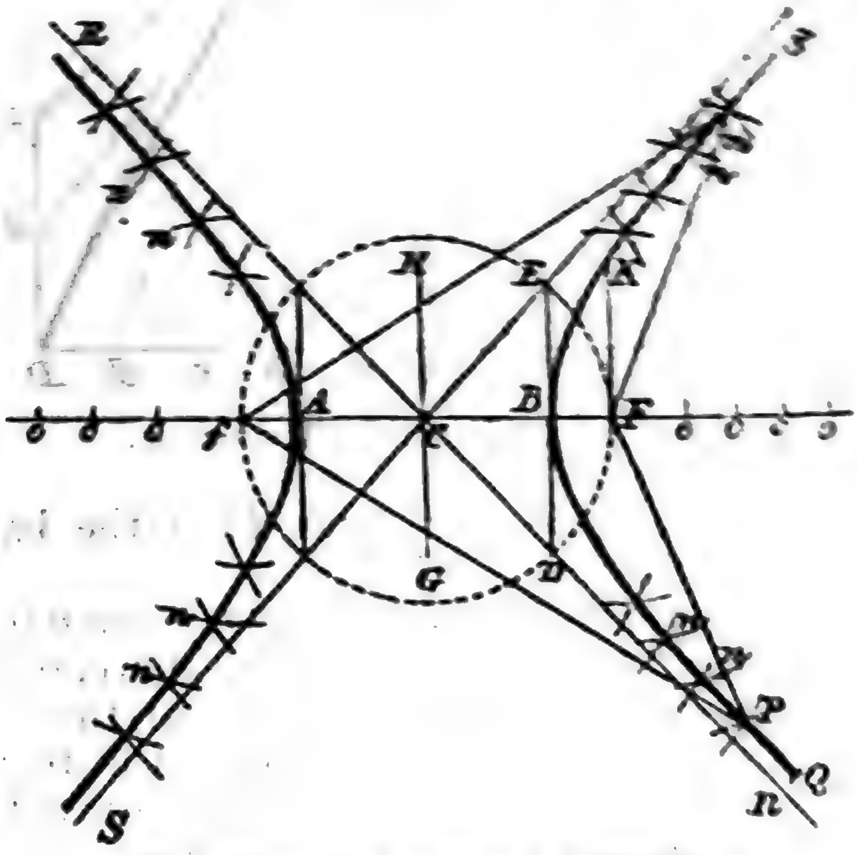


FIG. 10.—To describe a Hyperbola.

To describe a Hyperbola. Let the ends of two threads *f*PQ, FPQ, fig. 10, be fastened at the points *f* and F, and passed through a small bead or pin P, and knotted together at Q. Take hold of Q and draw the threads taut; move the bead along the threads, and the point P will describe the curve.

2nd Method. When the base CD, height AB, and transverse axis AA′, fig. 11, are given. Divide the base CD into a number of equal parts on each side of the axis at *a*, *b*, &c.; and divide the parallels CE, DF, into the same number of equal parts at *a*, *b*, &c. From the points *a*, *b*, &c., in the base, draw lines to A′; and from the points *a*, *b*, &c., in the verticals, draw lines to A, cutting the respective lines from the base. Trace the curve through the intersections.

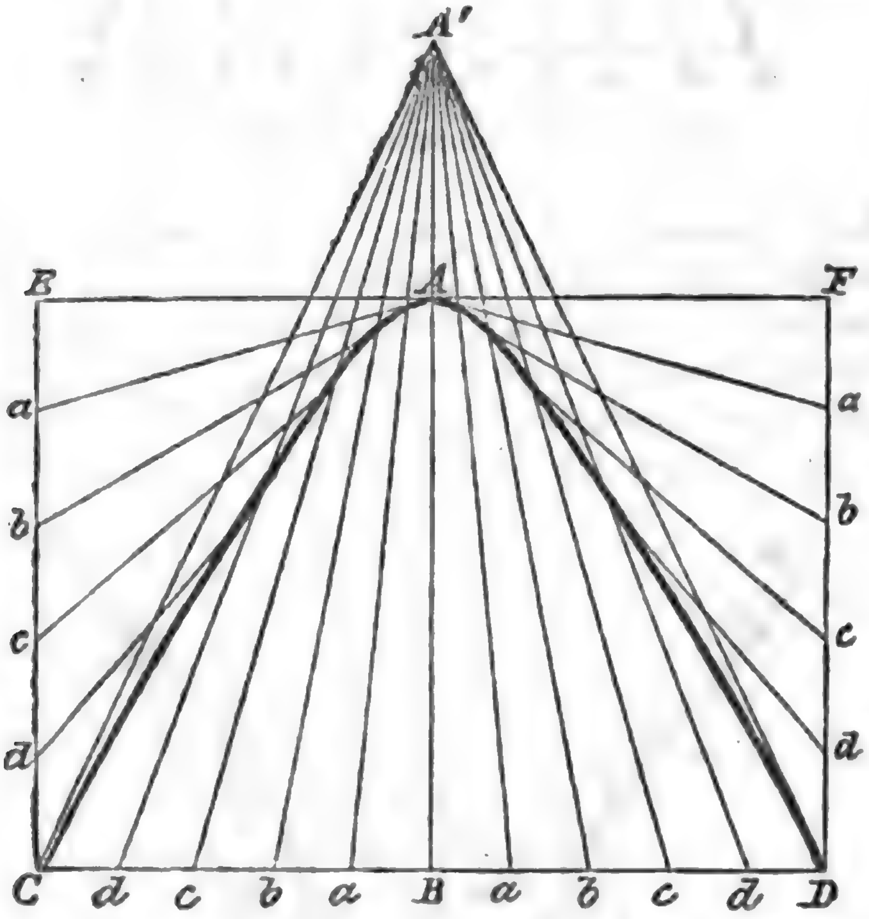


FIG. 11.—To describe a Hyperbola.

To describe a Right-angled Hyperbola, given a point in the curve. Let E, fig. 12, be a point in the curve, of which AB and AC, at right angles to each other, are the asymptotes. Draw the parallels DE and DC to complete the rectangle AE. Set off D*d* on the base line equal to AD, and draw the vertical *de*. Bisect AC at *b*, and draw *be* parallel to the base; the point of intersection, *e*, is a point in the curve. Similarly, bisecting A*b* at *c*, and A*c* at *n*; doubling A*d* to *d′*, and A*d′* to *d″*; and completing the rectangles *d′e′* and *d″e″*; and again bisecting and doubling; the points *e′* and *e″*, and *e‴* in the curve are found. By a like process of dividing and multiplying inversely, any additional number of points may be found, and the curve may be traced through the points.

This curve possesses the useful property that the elementary rectangles are equal in area.

The cycloid ADB, fig. 13, is the curved path described by any point D in the circumference of a wheel or a circle DGC which rolls along a straight line. The base AB for a complete revolution of the wheel, is equal in length to the circumference of the circle; the length of the curve is equal to four times the diameter of the circle; the area of the cycloid, ADBA, is equal to three times the area of the circle.

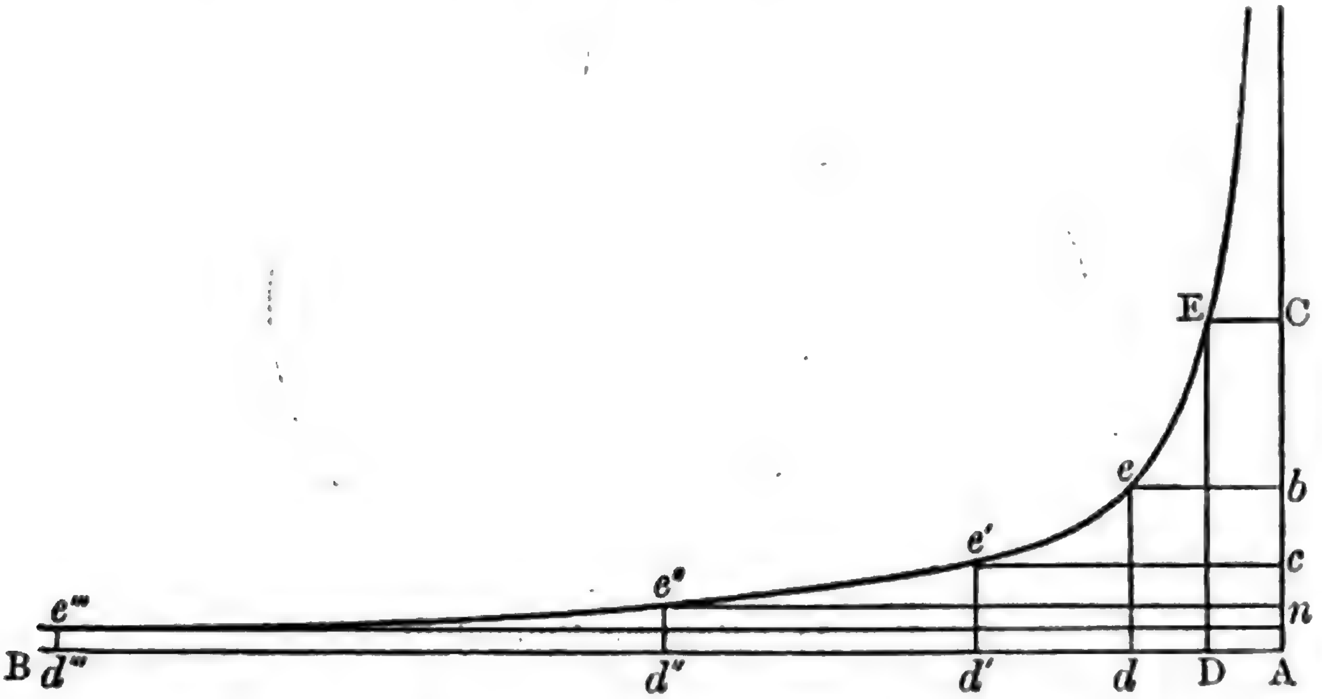


FIG. 12.—To describe a Right-Angled Hyperbola.

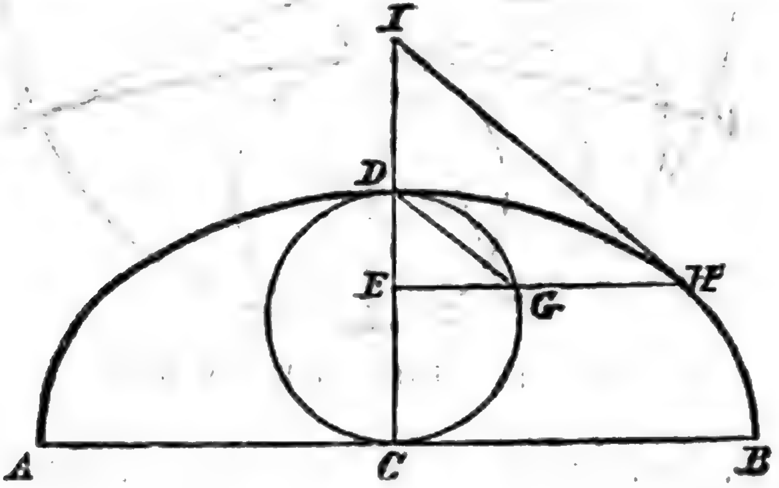


FIG. 13.—Cycloid.

The exterior epicycloid ADB, fig. 14, is the curve described by any point in the circumference of one circle, DC, rolling over another circle, ACB, on the outside of the circumference.

The hypocycloid, or interior epicycloid, ADB, fig. 15, is the

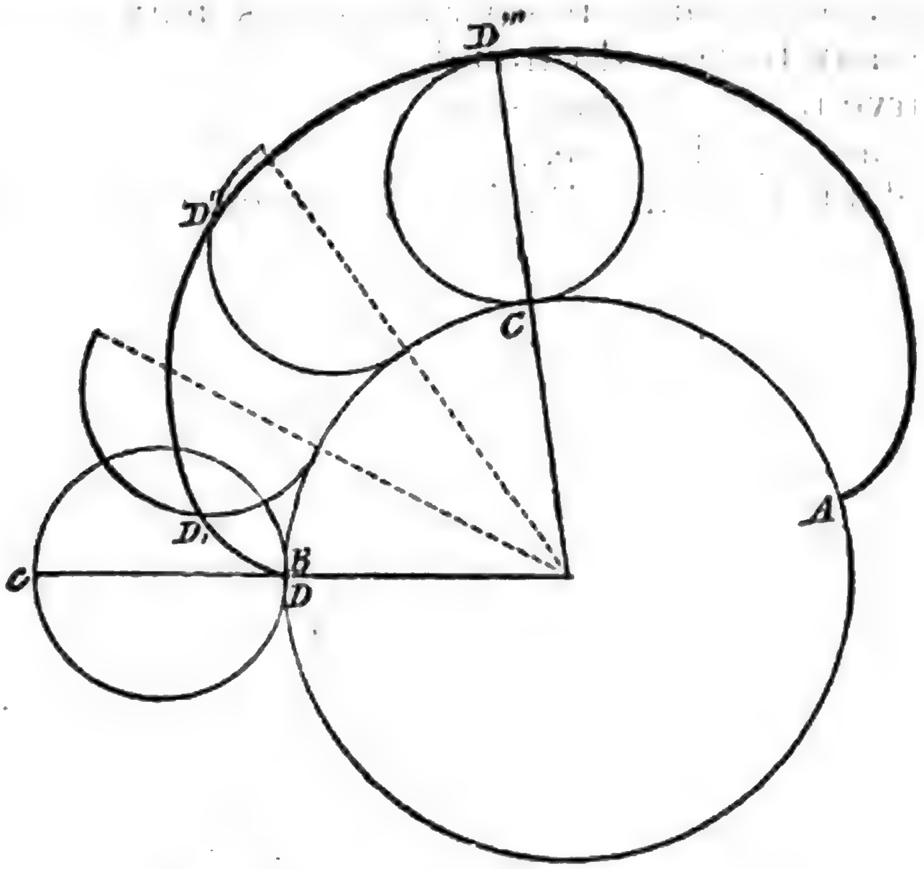


FIG. 14.—Exterior Epicycloid.

curve ADB described by a point in the circumference of a circle rolling on the inside of the circumference of another circle. When the diameter of the rolling circle is equal to half the diameter of the fixed circle, the curve becomes a straight line, or a diameter of the fixed circle.

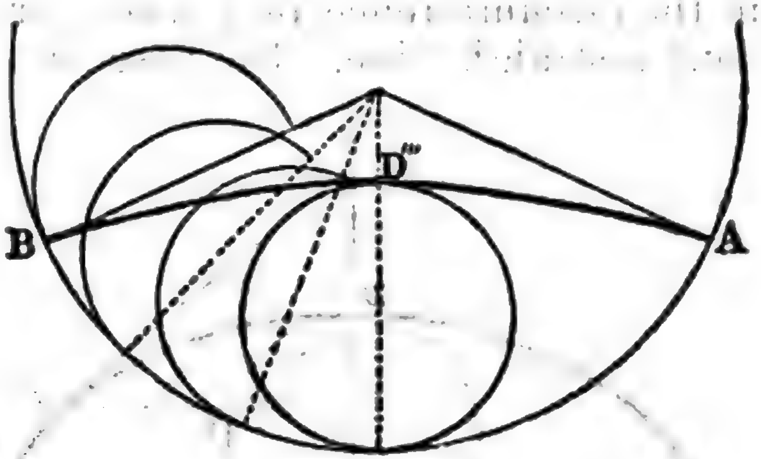


FIG. 15.—Interior Epicycloid.

WEIGHTS AND MEASURES.

THE yard and the pound are the units of English measure and weight.

The imperial standard yard is a solid square bar, 38 inches long, 1 inch square, of bronze or gun-metal, deposited in the Standards Department of the Board of Trade. The length of the yard is defined by lines inscribed on two gold plugs inserted near each end of the bar.

The imperial standard pound is a cylinder of platinum, nearly 1·35 inches in height, and 1·15 inches in diameter, having a groove or channel round it, near the top, by which it may be lifted.

Copies of the standard yard and the standard pound have been deposited in the Royal Mint and the Greenwich Observatory; copies have been immured in the New Palace at Westminster; and copies have been delivered to the Royal Society of London.

The unit or standard measure of capacity, for liquids as for dry goods, is the gallon, capable of containing ten imperial standard pounds weight of distilled water weighed in air against brass weights, at the temperature of 62° F., with the barometer at 30 inches. The standard measure is cylindrical, on a plane base, and the height is equal to the diameter.

The standard bushel, as a measure of capacity, is cylindrical, about 17·8 inches in diameter, with a plane base; the depth is half the diameter, about 8·9 inches. It has a capacity equal to 8 gallons.

In using an imperial measure of capacity, it is not to be heaped; but is either to be stricken with a round stick or cylindrical roller; or, if the article cannot be conveniently stricken, it is to be filled in all parts as nearly to the level of the brim as the size and shape of the article admits.

LIST OF GAUGES DEPOSITED AT THE STANDARDS OFFICE BY SIR JOSEPH WHITWORTH.

1 set, External plane gauges, containing 91 sizes, from ·01 to 0·1, rising by ·001 inch.

6 sets, Internal and External Cylindrical gauges, containing the following fractional sizes :—

1 set containing 15 gauges from $\frac{1}{8}$ inch to 1 inch, increasing by $\frac{1}{16}$ inch.
1 ,, ,, 8 ,, ,, $1\frac{1}{8}$ inches to 2 inches, increasing by $\frac{1}{8}$ inch.

1 set containing 8 gauges from 2⅛ inches to 3 inches, increasing by ⅛ inch.
1 „ „ 8 „ „ 3⅛ inches to 4 inches, increasing by ⅛ inch.
1 „ „ 4 „ „ 4¼ inches to 5 inches, increasing by ¼ inch.
1 „ „ 4 „ „ 5¼ inches to 6 inches, increasing by ¼ inch.

6 sets, containing the following decimal sizes :—

1 set containing 15 gauges, sizes, 0·10, 0·15, 0·2, 0·3, 0·35, 0·4, 0·45, 0·55, 0·60, 0·65, 0·7, 0·8, 0·85, 0·9, 0·95 inch.
1 „ „ 8 „ „ 1·1, 1·2, 1·3, 1·4, 1·6, 1·7, 1·8, 1·9 inches.
1 „ „ 8 „ „ 2·1, 2·2, 2·3, 2·4, 2·6, 2·7, 2·8, 2·9 inches.
1 „ „ 8 „ „ 3·1, 3·2, 3·3, 3·4, 3·6, 3·7, 3·8, 3·9 inches.
1 „ „ 4 „ „ 4·2, 4·4, 4·6, 4·8 inches.
1 „ „ 4 „ „ 5·2, 5·4, 5·6, 5·8 inches.

From 6 inches to 2 inches inclusive, the gauges are made of cast iron ; and below 2 inches they are made of steel.

The above collection of gauges is denominated as follows :—

(1.) Whitworth's External Cylindrical Gauges : external diameters in terms of the inch.

15 gauges from ⅛ inch to 1 inch, increasing by sixteenths of an inch.

24 gauges from 1⅛ inches to 4 inches, increasing by eighths of an inch.

8 gauges from 4¼ inches to 6 inches, increasing by quarters of an inch.

19 gauges from 0·1 inch to 1 inch, increasing by five one-hundredths of an inch.

30 gauges from 1·1 inches to 4 inches, increasing by tenths of an inch.

10 gauges from 4·2 inches to 6 inches, increasing by fifths of an inch.

(2.) Whitworth's Internal Cylindrical Gauges : internal diameters in terms of the inch : a repetition of section (1) preceding.

(3.) Whitworth's External Plane Gauges : thickness in terms of the inch.

91 gauges from ·01 inch to 0·1 inch, increasing by thousandths of an inch.

TABLE 15.—ENGLISH MEASURES OF LENGTH.

		French Equivalents.
12 lines 72 points 1000 mils	1 inch	25·4 millimetres.
7·92 inches	1 link	·2012 metre.
12 inches	1 foot	·3048 metre.
3 feet	1 yard	·91439 ,,
6 feet	1 fathom	1·82878 ,,
5½ yards	1 rod, pole, or perch	5·02915 ,,
100 links 66 feet	1 chain	20·1166 ,,
220 yards 40 poles 10 chains	1 furlong	201·1662 metres. 0·20117 kilometre.
8 furlongs 80 chains 1,760 yards 5,280 feet	1 mile	1609·3296 metres. 1·60933 kilometres.
1·1515 miles 6080 feet	1 Admiralty knot or nautical mile	1·85315 kilometres.

English Measures of Surface.

TABLE 16.—ORDINARY SUPERFICIAL MEASUREMENT.

1 square inch		645·15 square millimetres. 6·4515 square centimetres.
144 square inches 183·35 circular inches	1 square foot	·0929 square metre.
9 square feet	1 square yard	·8361 square metre.
100 square feet (for roofing and flooring)	1 square	9·2901 square metres.
30¼ square yards	1 square pole, rod, or perch	25·292 square metres.
40 square poles	1 rood	1011·696 square metres. 10·1170 ares.
4 roods 4840 square yards	1 acre[*]	4046·782 square metres. 40·4678 ares. ·4047 hectares.
640 acres	1 square mile	258·9894 hectares.

[*] The side of a square acre is equal to 69·57 lineal yards.

English Measures of Volume and Capacity.

TABLE 17.—SOLID OR CUBIC MEASURE.

1 cubic inch		16·387 cubic centimetres.
1728 cubic inches 2200·15 cylindrical inches 3300·23 spherical inches 6600·45 conical inches	1 cubic foot	28·3153 cubic decimetres. ·028315 cubic metre.
27 cubic feet	1 cubic yard	·764513 cubic metre.
1·308 cubic yard 31·3156 cubic feet		1 cubic metre.

TABLE 18.—DRY MEASURE.

	1 pint	·5679 litre.
2 pints	1 quart	1·1359 litres.
4 quarts (277·274 cubic inches)	1 gallon	4·5435 litres.
2 gallons	1 peck	9·0869 litres.
4 pecks (1·28366 cubic feet)	1 bushel	36·3477 litres.
8 bushels	1 quarter	290·782 litres.
4 quarters (41·077 cubic feet)	1 chaldron	1·1631 cubic metres.
5 quarters	1 load, or way	1·4539 cubic metres.
2 loads	1 last	2·9078 cubic metres.

Builders' Measurement.

TABLE 19.—LINEAL MEASURE.

12 inches	1 foot.
3 feet	1 yard.
16½ feet	1 rod.

The rod of 16½ feet lineal is used for measuring park-fencing.

Rubble-walling, in some parts of England, is measured by the rod of 16½ feet, by 1 foot high; and the various thicknesses are stated.

TABLE 20.—SUPERFICIAL MEASURE.

1 part	1 square inch.
12 parts	1 inch (12 square inches).
12 inches	1 foot.
9 feet	1 yard.
100 feet	1 square.
272¼ feet	1 rod.

Brickwork generally is measured by the rod of 272 feet superficial (not 272¼ feet) reduced to 1½ bricks in thickness.

But, for engineering works, it is measured by the cubic yard of 27 cubic feet.

Flooring, slating, and tiling, are measured by the square.

Paving, painting, plastering, &c., are measured by the yard.

TABLE 21.—CUBIC MEASURE.

1 third	1 cubic inch.
12 thirds	1 part (12 cubic inches).
12 parts	1 inch (144 cubic inches).
12 inches	1 foot (1728 cubic inches).
27 feet	1 yard.

Excavation, concrete, &c., are measured by the cubic yard.

Masonry, square-sided timber, &c., are measured by the cubic foot.

Timber.

The inscribed square in the section of a round tree gives the maximum of sectional area, but not the maximum of transverse strength. To find the strongest section, draw a diameter *a b*; from the centre *o* set off *o c*, one-third of the radius *o b*, and draw the perpendicular *c d*. Draw *d b* and *d a*, and complete the parallelogram. The area of the parallelogram is 6 per cent. less than that of the square section; but it is 9 per cent. stronger.

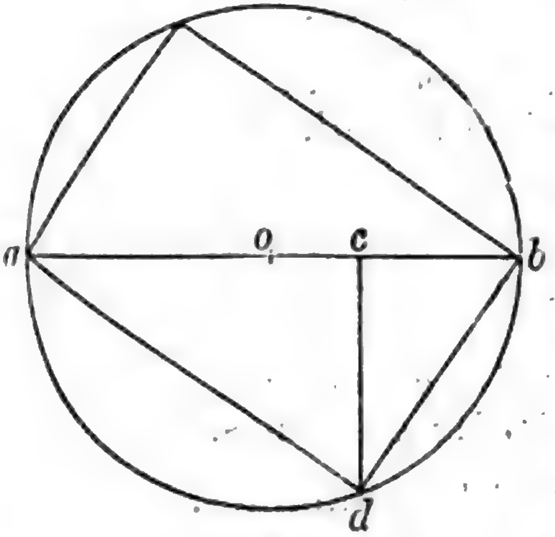


FIG. 16.—To find Strongest Section of Round Tree.

TABLE 22.—LIQUID MEASURE.

8·665 cubic inches	1 gill or quartern	·1420 litre.
4 gills	1 pint	·5679 litre.
2 pints	1 quart	1·1359 litres.
4 pints	1 pottle	2·2718 litres.
8 pints 4 quarts (277·274 cubic inches)	1 gallon	4·5435 litres.
6·2355 gallons	1 cubic foot.	
168·3765 gallons	1 cubic yard.	
220·09 gallons		1 cubic metre.

TABLE 23.—OLD WINE AND SPIRIT MEASURE.

		Imperial Gallons.
4 gills or quarterns	1 pint.	
2 pints	1 quart.	
4 quarts (231·06 cubic inches)	1 gallon	= ·8333, or ⅚.

		Imperial gallons.
31½ gallons	1 barrel	= 26·25.
63 gallons 2 barrels	1 hogshead	= 52·5.
84 gallons	1 puncheon	= 70.
126 gallons	1 pipe or butt	= 105.
2 pipes	1 tun	= 210.

Wines, spirits, oils, &c., are measured by this scale; but the contents of casks are reckoned in imperial gallons when sold.

TABLE 24.—APOTHECARIES' FLUID MEASURE (ENGLISH).

60 minims (♏)	1 fluid drachm (*f* ʒ).
8 drachms (water 1·732 cubic inches, 437½ grains)	1 fluid ounce (*f* ℥).
20 ounces	1 pint (*o*).
80 pints (water, 70,000 grains)	1 gallon (gall.)
4 drachms	1 tablespoonful.
2 ounces (water, 875 grains)	1 wineglassful.
3 ounces	1 teacupful.

TABLE 25.—AVOIRDUPOIS WEIGHT.

1 grain		·0648 gramme.
27·344 grains	1 drachm	1·7718 grammes.
16 drachms 437½ grains	1 ounce	28·3495 grammes.
16 ounces 7000 grains	1 pound	453·5926 grammes. ·45359$_3$ kilogrammes.
14 pounds	1 stone	6·3503 kilogrammes.
28 pounds	1 quarter	12·7006 kilogrammes.
4 quarters 112 pounds	1 hundredweight	50·8024 kilogrammes.
20 hundredweights 2240 pounds	1 ton	1016·048 kilogrammes. 1·01605 metric ton.

TABLE 26.—TROY WEIGHT.

24 grains	1 pennyweight	1·5552 grammes.
20 pennyweights 480 grains	1 troy ounce	31·1035 grammes.
12 troy ounces 5760 grains	1 troy pound	373·2419 grammes. ·37324 kilogramme.
25 pounds	1 troy quarter	9·3310 kilogrammes.
4 quarters 100 pounds	1 troy hundredweight	37·3242 kilogrammes.

TABLE 27.—COAL WEIGHT (ENGLISH).

14 pounds	1 stone	6·3503 kilogrammes.
88 pounds	1 bushel	
1 sack of 112 pounds	1 hundredweight	50·8024 kilogrammes.
20 hundredweights	1 ton	1·01605 metric ton.
26½ hundredweights	1 chaldron (London)	1·3462 metric ton.
53 hundredweights	1 chaldron (Newcastle)	2·6924 metric tons.

Sundry bushels of coal.—Cornish, 90 or 94 pounds ; heaped, 101 pounds ; Welsh, 93 pounds ; Newcastle, 80 or 84 pounds ; London, 80 or 84 pounds.

The “ colliery ton ” is 21 cwt. of 120 lbs. each.

TABLE 28.—HAY AND STRAW WEIGHT (ENGLISH).

1 truss of straw	36 pounds.
1 load of straw	11 hundredweights, 64 pounds.
1 truss of old hay	56 pounds.
1 load of old hay	18 hundredweights.
1 truss of new hay	60 pounds.
1 load of new hay	19 hundredweights, 32 pounds.
1 cubic yard of compact old hay	15 stones.

Loose hay, 5 pounds per cubic foot ; ordinarily pressed, as in a stack, 8 pounds ; close pressed, as in a bale, 12 to 14 pounds ; ordinarily pressed, as in a waggon-load, from 450 to 500 cubic feet weigh 1 ton.—*Haswell.*

TABLE 29.—CORN AND FLOUR WEIGHT (ENGLISH).

1 peck, or stone, of flour		14	pounds
10 pecks	1 boll	140	„
2 bolls	1 sack	280	„
14 pecks	1 barrel	196	„
1 bushel of wheat		60	„
1 bushel of barley		47	„
1 bushel of oats		40	„
80 bushels of corn		1 last.	

Six bushels of wheat should yield one sack of flour.

TABLE 30.—TIMBER MEASURES FOR BUILDING PURPOSES (ENGLISH).

Load of timber, unhewn or rough	40 cubic feet.
Load, hewn or squared	50 cubic feet, reckoned to weigh 20 cwt.

Stack of wood	108 cubic feet.
Cord of wood	128 ,,

(In dockyards, 40 cubic feet of hewn timber are reckoned to weigh 20 cwt.; 50 cubic feet is a load.)

100 superficial feet of boarding or flooring	1 square.
Hundred of deals	120 deals.
Load of 1-inch plank	600 square feet.
Load of 1½-inch plank	400 ,,
Load of 2-inch	300 ,,
Load of 2½-inch	240 ,,
Load of 3-inch	200 ,,
Load of 3½-inch	170 ,,
Load of 4-inch	150 ,,
Planks, section	11 by 3 inches.
Deals, section	9 by 3 ,,
Battens, section	7 by 2½ ,,

A reduced deal is 1½ inches thick, 11 inches wide, and 12 feet long.

Bundle of 4 feet oak-heart laths	120 laths.
Load of ,, ,,	37½ bundles.
Bundle of 5 feet oak-heart laths	100 laths.
Load of ,, ,,	30 bundles.

Sundry Building Materials.

Load of statute bricks	500.
Load of plain tiles	1000.
Load of lime	32 bushels.
Load of sand	36 ,,
Hundred of lime	35 ,,
Hundred of nails, or tacks	120.
Thousand of nails, or tacks	1200.
Fodder of lead	19½ cwt.
Sheet lead	6 to 10 pounds per sq. ft.
Hundred of lead	112 pounds.
Table of glass	5 feet.
Case of glass	45 tables.
Case of glass	(Newcastle and Normandy glass, 25 tables.)
Stone of glass	5 pounds.
Seam of glass	24 stone.

TABLE 31.—ENGLISH BRICKWORK MEASURES (Mackrow).

	ins. ins. ins.	Weight.
London stock bricks	8¾ × 4¼ × 2¾	6·81 lbs.
Red kiln	8¾ × 4¼ × 2¾	7·00 ,,
Welsh fire	9 × 4½ × 2¾	7·84 ,,

	ins. ins. ins.	Weight.
Paving	9 × 4½ × 1¾	5·00 lbs.
Square tiles	9¾ × 9¾ × 1	5·70 „
do.	6 × 6 × 1	2·16 „

A rod of brickwork is,—
16½ feet × 16½ feet × 1½ bricks thick ;
306 cubic feet, or 11⅓ cubic yards ;
272 superficial feet 1½ bricks thick ;
4352 stock bricks, 4 courses 1 foot high.

Bricks absorb about $\frac{1}{16}$th of their weight of water.

A rod of brick-work requires about 3 cubic yards of mortar, or 1½ cubic yards of chalk lime and 3 loads of sand, or 1 cubic yard of stone lime and 3½ loads of sand, or 36 bushels of cement and an equal quantity of sand.

A load of mortar or of sand is 1 cubic yard.

A bag of cement is 3 bushels.

A sack of cement is 5 bushels.

A load of mortar requires about 9 bushels of lime and 1 cubic yard or load of sand.

One load of bricks, 500 bricks.

330 stock bricks weigh 1 ton.

1000 bricks loosely stacked occupy about 72 cubic feet (14 bricks per cubic foot).

1000 bricks closely stacked occupy about 56 cubic feet (18 bricks per cubic foot).

Mortar is composed of 1 part of lime to 3 or 3½ parts of sharp sand.

Concrete is composed of 1 part of lime, 4 parts of gravel, and 2 parts of sand.

Cement is composed of 1 part of Portland cement to 3 parts of sand. Or cement alone may be used.

TABLE 32.—TONNAGE OF SHIPS (ENGLISH).

1 ton, displacement of a ship	35 cubic feet.
1 ton, freight by measurement	40 „
1 ton, registered internal capacity of a ship	100 „
1 ton, shipbuilders' old measurement	94 „

Wire-Gauges.

The oldest and best-known Birmingham Wire-Gauge is that of which the numbers were carefully measured by Mr. Holtzapffel, and published by him in 1847. He gives 40 measurements ranging from ·454 inch to ·004 inch, as recorded in Table 33. It was accepted by the Standards Department of the Board of Trade. Although there are only 40 marks in the table, there were 60 different sizes of wire made, for which intermediate sizes were added to the gauge.

TABLE 33.—BIRMINGHAM WIRE-GAUGE.

(Stubs.)

Mark.	Size.	Mark.	Size.	Mark.	Size.	Mark.	Size.
No.	Inch.	No.	Inch.	No.	Inch.	No.	Inch.
4/0	·454	7	·180	17	·058	27	·016
3/0	·425	8	·165	18	·049	28	·014
2/0	·380	9	·148	19	·042	29	·013
0	·340	10	·134	20	·035	30	·012
1	·300	11	·120	21	·032	31	·010
2	·284	12	·109	22	·028	32	·009
3	·259	13	·095	23	·025	33	·008
4	·238	14	·083	24	·022	34	·007
5	·220	15	·072	25	·020	35	·005
6	·203	16	·065	26	·018	36	·004

The wire-gauge that has been in common use by the sheet-rollers of South Staffordshire, ranges from $\frac{5}{16}$ inch to $\frac{1}{80}$ inch in thickness, according to the following Table :—

TABLE 34.—BIRMINGHAM WIRE-GAUGE.

For Iron Sheets chiefly.

No.	Size.	No.	Size.	No.	Size.	No.	Size.
	Inch.		Inch.		Inch.		Inch.
1	·3125 $(^5/_{16})$	9	·15625	17	·05625	25	·02344
2	·28125	10	·140625	18	·05 $(^1/_{20})$	26	·021875
3	·25 $(^1/_4)$	11	·125 $(^1/_8)$	19	·04375	27	·020312
4	·234375	12	·1125	20	·0375	28	·01875
5	·21875	13	·10 $(^1/_{10})$	21	·034375	29	·01719
6	·203125	14	·0875	22	·03125 $(^1/_{32})$	30	·015625
7	·1875 $(^3/_{16})$	15	·075	23	·028125	31	·01406
8	·171875	16	·0625 $(^1/_{16})$	24	·025 $(^1/_{40})$	32	·0125 $(^1/_{80})$

Sir Joseph Whitworth, in 1857, promulgated his Standard Wire-Gauge, ranging from half an inch to one-thousandth of an inch, and comprising 62 measurements, given in Table 35. The sizes are designated or marked by their respective values. The Whitworth gauge has been in general use.

TABLE 35.—WHITWORTH WIRE-GAUGE, 1857.

Mark.	Size.	Mark.	Size.	Mark.	Size.	Mark.	Size.
No.	Inch.	No.	Inch.	No.	Inch.	No.	Inch.
1	·001	17	·017	55	·055	200	·200
2	·002	18	·018	60	·060	220	·220
3	·003	19	·019	65	·065	240	·240
4	·004	20	·020	70	·070	260	·260
5	·005	22	·022	75	·075	280	·280
6	·006	24	·024	80	·080	300	·300
7	·007	26	·026	85	·085	325	·325
8	·008	28	·028	90	·090	350	·350
9	·009	30	·030	95	·095	375	·375
10	·010	32	·032	100	·100	400	·400
11	·011	34	·034	110	·110	425	·425
12	·012	36	·036	120	·120	450	·450
13	·013	38	·038	135	·135	475	·475
14	·014	40	·040	150	·150	500	·500
15	·015	45	·045	165	·165		
16	·016	50	·050	180	·180		

TABLE 36.—IMPERIAL STANDARD WIRE-GAUGE.

Descriptive Number.	Equivalents in Parts of an Inch.	Metric Equivalents.	Sectional Area of Wire.	
No.	Inch.	Millimetres.	Square Inch.	Square Millimetres.
7/0	·500	12·700	·1963	126·67
6/0	·464	11·785	·1691	109·09
5/0	·432	10·973	·1466	94·56
4/0	·400	10·160	·1257	81·07
3/0	·372	9·449	·1087	70·12
2/0	·348	8·839	·0951	61·36
0	·324	8·229	·0824	53·19
1	·300	7·620	·0707	45·60
2	·276	7·010	·0598	38·58
3	·252	6·401	·0499	32·18
4	·232	5·893	·0423	27·27
5	·212	5·385	·0353	22·77
6	·192	4·877	·0289	18·68
7	·176	4·470	·0243	15·70
8	·160	4·064	·0201	12·97
9	·144	3·658	·0163	10·51

TABLE 36.—IMPERIAL STANDARD WIRE-GAUGE (*continued*).

Descriptive Number.	Equivalents in Parts of an Inch.	Metric Equivalents.	Sectional Area of Wire.	
No.	Inch.	Millimetres.	Square Inch.	Square Millimetres.
10	·128	3·251	·0129	8·30
11	·116	2·946	·0106	6·82
12	·104	2·642	·00849	5·48
13	·092	2·337	·00665	4·29
14	·080	2·032	·00503	3·24
15	·072	1·829	·00407	2·63
16	·064	1·626	·00322	2·07
17	·056	1·422	·00246	1·59
18	·048	1·219	·00181	1·17
19	·040	1·016	·00126	·811
20	·036	·914	·00102	·657
21	·032	·813	·000804	·519
22	·028	·711	·000616	·397
23	·024	·610	·000452	·292
24	·022	·559	·000380	·245
25	·020	·508	·000314	·203
26	·018	·457	·000254	·164
27	·0164	·4166	·000211	·136
28	·0148	·3759	·000173	·111
29	·0136	·3454	·000145	·0937
30	·0124	·3150	·000121	·0779
31	·0116	·2946	·000106	·0682
32	·0108	·2743	·0000916	·0591
33	·0100	·2540	·0000785	·0507
34	·0092	·2337	·0000665	·0429
35	·0084	·2134	·0000554	·0357
36	·0076	·1930	·0000454	·0293
37	·0068	·1727	·0000363	·0234
38	·0060	·1524	·0000283	·0182
39	·0052	·1321	·0000212	·0137
40	·0048	·1219	·0000181	·0117
41	·0044	·1118	·0000152	·00982
42	·0040	·1016	·0000126	·00811
43	·0036	·0914	·0000102	·00656
44	·0032	·0813	·00000804	·00519
45	·0028	·0711	·00000616	·00397
46	·0024	·0610	·00000452	·00292
47	·0020	·0508	·00000314	·00203
48	·0016	·0406	·00000201	·00129
49	·0012	·0305	·00000113	·00073
50	·0010	·0254	·000000785	·00051

TABLE 37.—WARRINGTON WIRE GAUGE.

(Rylands Brothers.)

(Rarely used now.)

Mark.	Size.	Mark.	Size.	Mark.	Size.
No.	Inch.	No.	Inch.	No.	Inch.
7/0	$\frac{1}{2}$	4	·229	13	·090
6/0	$\frac{15}{32}$	5	·209	14	·079
5/0	$\frac{7}{16}$	6	·191	15	·069
4/0	$\frac{13}{32}$	7	·174	16	·0625 or $\frac{1}{16}$
3/0	$\frac{3}{8}$	8	·159	17	·053
2/0	$\frac{11}{32}$	9	·146	18	·047
0	·326	10	·135	19	·041
1	·300	10½	·125 or $\frac{1}{8}$	20	·036
2	·274	11	·117	21	·0315 or $\frac{1}{32}$
3	·250 or $\frac{1}{4}$	12	·100 or $\frac{1}{10}$	22	·028

TABLE 38.—HOLTZAPFFEL'S LANCASHIRE GAUGE.

(For Round Steel Wire and Pinion Wire.)

Mark.	Size.	Mark.	Size.	Mark.	Size.	Mark.	Size.	Mark.	Size.
No.	Inch.	No.	Inch.	No.	Inch.	No.	Inch.	No.	Inch.
80	·013	57	·042	34	·109	11	·189	M	·295
79	·014	56	·044	33	·111	10	·190	N	·302
78	·015	55	·050	32	·115	9	·191	O	·316
77	·016	54	·055	31	·118	8	·192	P	·323
76	·018	53	·058	30	·125	7	·195	Q	·332
75	·019	52	·060	29	·134	6	·198	R	·339
74	·022	51	·064	28	·138	5	·201	S	·348
73	·023	50	·067	27	·141	4	·204	T	·358
72	·024	49	·070	26	·143	3	·209	U	·368
71	·026	48	·073	25	·146	2	·219	V	·377
70	·027	47	·076	24	·148	1	·227	W	·386
69	·029	46	·078	23	·150	A	·234	X	·397
68	·030	45	·080	22	·152	B	·238	Y	·404
67	·031	44	·084	21	·157	C	·242	Z	·413
66	·032	43	·086	20	·160	D	·246	A1	·420
65	·033	42	·091	19	·164	E	·250	B1	·431
64	·034	41	·095	18	·167	F	·257	C1	·443
63	·035	40	·096	17	·169	G	·261	D1	·452
62	·036	39	·098	16	·174	H	·266	E1	·462
61	·038	38	·100	15	·175	I	·272	F1	·475
60	·039	37	·102	14	·177	Kj	·277	G1	·484
59	·040	36	·105	13	·180	K	·281	H1	·494
58	·041	35	·107	12	·185	L	·290		

The Imperial Standard Wire-Gauge was legally established March 1, 1884. It is given in Table 36.

The Warrington Wire-Gauge, formerly practised by Rylands Brothers, is given in Table 37. It is rarely used now.

The Lancashire Gauge, Table 38, arranged by Holtzapffel, is employed for the manufacture of bright steel wire in Lancashire, and steel pinion-wire used in clocks and watches. The larger sizes, distinguished by letters, form the *Letter-Gauge.*

There are also the Needle-gauge, for needle-wire, and the Music Wire-gauge, for the strings of pianofortes.

TABLE 39.—ADMIRALTY KNOTS AND STATUTE MILES.

Knots.	Miles.	Knots.	Miles.	Knots.	Miles.	Knots.	Miles.
·10	·1152	5·50	6·3333	12·25	14·1061	18·75	21·5909
·20	·2303	5·75	6·6212	12·50	14·3939	19·00	21·8788
·30	·3455	6·00	6·9091	12·75	14·6818	19·25	22·1667
·40	·4606	6·25	7·1970	13·00	14·9697	19·50	22·4545
·50	·5758	6·50	7·4848	13·25	15·2576	19·75	22·7424
·60	·6909	6·75	7·7727	13·50	15·5455	20·00	23·0303
·70	·8061	7·00	8·0606	13·75	15·8333	20·50	23·6061
·80	·9212	7·25	8·3485	14·00	16·1212	21·00	24·1818
·90	1·0363	7·50	8·6364	14·25	16·4091	21·50	24·7576
1·00	1·1515	7·75	8·9242	14·50	16·6970	22·00	25·3333
1·25	1·4394	8·00	9·2121	14·75	16·9848	22·50	25·9091
1·50	1·7273	8·25	9·5000	15·00	17·2727	23·00	26·4848
1·75	2·0152	8·50	9·7879	15·25	17·5606	23·50	27·0606
2·00	2·3030	8·75	10·0758	15·50	17·8485	24·00	27·6364
2·25	2·5909	9·00	10·3636	15·75	18·1364	24·50	28·2121
2·50	2·8788	9·25	10·6515	16·00	18·4242	25·00	28·7879
2·75	3·1667	9·50	10·9394	16·25	18·7121	25·50	29·3636
3·00	3·4546	9·75	11·2273	16·50	19·0000	26·00	29·9393
3·25	3·7424	10·00	11·5152	16·75	19·2879	26·50	30·5151
3·50	4·0303	10·25	11·8030	17·00	19·5758	27·00	31·0908
3·75	4·3182	10·50	12·0909	17·25	19·8636	27·50	31·6668
4·00	4·6061	10·75	12·3788	17·50	20·1515	28·00	32·2426
4·25	4·8939	11·00	12·6667	17·75	20·4394	28·50	32·8183
4·50	5·1818	11·25	13·9545	18·00	20·7273	29·00	33·3941
4·75	5·4697	11·50	13·2424	18·25	21·0512	29·50	33·9698
5·00	5·7576	11·75	12·5303	18·50	21·3030	30·00	34·5456
5·25	6·0455	12·00	13·8182				

TABLE 40.—VULGAR FRACTIONS OF A LINEAL INCH IN DECIMAL FRACTIONS.

Advancing by Eighths.

Eighths.	Fractions.	Decimals of an Inch.	Eighths.	Fractions.	Decimals of an Inch.
1	$\frac{1}{8}$	·125	5	$\frac{5}{8}$	·625
2	$\frac{1}{4}$	·25	6	$\frac{3}{4}$	·75
3	$\frac{3}{8}$	·375	7	$\frac{7}{8}$	·875
4	$\frac{1}{2}$	·5	8	1	1·0

Advancing by Twelfths.

Twelfths.	Fractions.	Decimals of an Inch.	Twelfths.	Fractions.	Decimals of an Inch.
1	$\frac{1}{12}$	·083$\dot{3}$	7	$\frac{7}{12}$	·583$\dot{3}$
2	$\frac{1}{6}$	·166$\dot{6}$	8	$\frac{2}{3}$	·666$\dot{6}$
3	$\frac{1}{4}$	·25	9	$\frac{3}{4}$	·75
4	$\frac{1}{3}$	·333$\dot{3}$	10	$\frac{5}{6}$	·833$\dot{3}$
5	$\frac{5}{12}$	·416$\dot{6}$	11	$\frac{11}{12}$	·916$\dot{6}$
6	$\frac{1}{2}$	·5	12	1	1·0

Advancing by Sixteenths.

Sixteenths.	Fractions.	Decimals of an Inch.	Sixteenths.	Fractions.	Decimals of an Inch.
1	$\frac{1}{16}$	·0625	9	$\frac{9}{16}$	·5625
2	$\frac{1}{8}$	·125	10	$\frac{5}{8}$	·625
3	$\frac{3}{16}$	·1875	11	$\frac{11}{16}$	·6875
4	$\frac{1}{4}$	·25	12	$\frac{3}{4}$	·75
5	$\frac{5}{16}$	·3125	13	$\frac{13}{16}$	·8125
6	$\frac{3}{8}$	·375	14	$\frac{7}{8}$	·875
7	$\frac{7}{16}$	·4375	15	$\frac{15}{16}$	·9375
8	$\frac{1}{2}$	·5	16	1	1·0

TABLE 40.—VULGAR FRACTIONS OF A LINEAL INCH IN DECIMAL FRACTIONS (*continued*).

Advancing by Thirty-seconds.

Thirty-seconds.	Fractions	Decimals of an Inch.	Thirty-seconds.	Fractions.	Decimals of an Inch.
1	$\frac{1}{32}$	·03125	17	$\frac{17}{32}$	·53125
2	$\frac{1}{16}$	·0625	18	$\frac{9}{16}$	·5625
3	$\frac{3}{32}$	·09375	19	$\frac{19}{32}$	·59375
4	$\frac{1}{8}$	·125	20	$\frac{5}{8}$	·625
5	$\frac{5}{32}$	·15625	21	$\frac{21}{32}$	·65625
6	$\frac{3}{16}$	·1875	22	$\frac{11}{16}$	·6875
7	$\frac{7}{32}$	·21875	23	$\frac{23}{32}$	·71875
8	$\frac{1}{4}$	·25	24	$\frac{3}{4}$	·75
9	$\frac{9}{32}$	·28125	25	$\frac{25}{32}$	·78125
10	$\frac{5}{16}$	·3125	26	$\frac{13}{16}$	·8125
11	$\frac{11}{32}$	·34375	27	$\frac{27}{32}$	·84375
12	$\frac{3}{8}$	·375	28	$\frac{7}{8}$	·875
13	$\frac{13}{32}$	·40625	29	$\frac{29}{32}$	·90625
14	$\frac{7}{16}$	·4375	30	$\frac{15}{16}$	·9375
15	$\frac{15}{32}$	·46875	31	$\frac{31}{32}$	·96875
16	$\frac{1}{2}$	·5	32	1	1·0

Advancing by odd Sixty-fourths.

Sixty-fourths.	Decimals of an Inch.	Sixty-fourths.	Decimals of an Inch.
1	·015625	35	·546875
3	·031250	37	·578125
5	·078125	39	·609375
7	·109375	41	·640625
9	·140625	43	·671875
11	·171875	45	·703125
13	·203125	47	·734375
15	·234375	49	·765625
17	·265625	51	·796875
19	·296875	53	·828125
21	·328125	55	·859375
23	·359375	57	·890625
25	·390625	59	·921875
27	·421875	61	·953125
29	·453125	63	·984375
31	·484375	64	1·0
33	·515625		

TABLE 41.—LINEAL INCHES IN DECIMAL FRACTIONS OF A LINEAL FOOT.

Lineal Inches.	Lineal Foot.	Lineal Inches.	Lineal Foot.	Lineal Inches.	Lineal Foot.
1/64	·001302083̇	1 7/8	·15625	6 1/2	·5416̇
1/32	·00260416̇	2	·1666̇	6 3/4	·5625
1/16	·0052083̇	2 1/8	·177083̇	7	·5833̇
1/8	·010416̇	2 1/4	·1875	7 1/4	·60416̇
3/16	·015625	2 3/8	·197916̇	7 1/2	·625
1/4	·02083̇	2 1/2	·2083̇	7 3/4	·64583̇
5/16	·0260416̇	2 5/8	·21875	8	·6666̇
3/8	·03125	2 3/4	·22916̇	8 1/4	·6875
7/16	·0364583	2 7/8	·239583̇	8 1/2	·7083
1/2	·0416̇	3	·25	8 3/4	·72916̇
9/16	·046875	3 1/4	·27083̇	9	·75
5/8	·052083̇	3 1/2	·2916̇	9 1/4	·77083̇
11/16	·0572916̇	3 3/4	·3125	9 1/2	·7916̇
3/4	·0625	4	·3333̇	9 3/4	·8125
13/16	·0677083̇	4 1/4	·35416̇	10	·8333̇
7/8	·072916̇	4 1/2	·375	10 1/4	·85416̇
15/16	·078125	4 3/4	·39583̇	10 1/2	·875
1	·0833̇	5	·4166̇	10 3/4	·89583̇
1 1/8	·09875	5 1/4	·4375	11	·9166̇
1 1/4	·10416̇	5 1/2	·4583̇	11 1/4	·9375
1 3/8	·114583̇	5 3/4	·47916̇	11 1/2	·9583̇
1 1/2	·125	6	·5	11 3/4	·97916̇
1 5/8	·135416̇	6 1/4	·52083̇	12	1·0000
1 3/4	·14583̇				

TABLE 40.—VULGAR FRACTIONS
DECIMAL FRACTIONS

Advancing by Thir

Thirty-seconds.	Fractions	Decimals of an Inch.	Thi seco
1	$\frac{1}{32}$	·03125	17
2	$\frac{1}{16}$	·0625	18
3	$\frac{3}{32}$	·09375	19
4	$\frac{1}{8}$	·125	20
5	$\frac{5}{32}$	·15625	21
6	$\frac{3}{16}$	·1875	22
7	$\frac{7}{32}$	·21875	23
8	$\frac{1}{4}$	·25	24
9	$\frac{9}{32}$	·28125	25
10	$\frac{5}{16}$	·3125	26
11	$\frac{11}{32}$	·34375	27
12	$\frac{3}{8}$	·375	28
13	$\frac{13}{32}$	·40625	29
14	$\frac{7}{16}$	·4375	30
15	$\frac{15}{32}$	·46875	31
16	$\frac{1}{2}$	·5	32

Advancing by odd Sixty-fo

Sixty-fourths.		Decimals of an Inch.	Sixty-fourths.
1			35
3			37
5			
7			
9			
11			
13			
[illegible]			

Square Inches.	Square Feet.
105	·72916
106	·73611
107	·74305
108	·75000
109	·75694
110	·76388
111	·77083
112	·77777
113	·78472
114	·79166
115	·79861
116	·80555
117	·81249
118	·81944
119	·82638
120	·83333
121	·84027
122	·84722
123	·85416
124	·86111
125	·86805
126	[illegible]
127	[illegible]
128	[illegible]
[illegible]	[illegible]

Square Inches.	Square Foot.	Square Inches.	Square Foot.	Square Inches.
37·4	·51	73·4	·76	109·4
38·9	·52	74·9	·77	110·9
40·3	·53	76·3	·78	112·3
41·8	·54	77·8	·79	113·8
43·2	·55	79·2	·80	115·2
44·6	·56	80·6	·81	116·6
46·1	·57	82·1	·82	118·1
47·5	·58	83·5	·83	119·5
9·0	·59	85·0	·84	121·0
0·4	·60	86·4	·85	122·4
·8	·61	87·8	·86	123·8
·3	·62	89·3	·87	125·3
7	·63	90·7	·88	126·7
	·64	92·2	·89	128·2
	·65	93·6	·90	129·6
	·66	95·0	·91	131·0
	·67	96·5	·92	132·5
	·68	97·9	·93	133·9
	·69	99·4	·94	135·4
	·70	100·8	·95	136·8
	·71	102·2	·96	138·2
	72	103·7	·97	139·7
	3	105·1	·98	141·1
		106·6	·99	142·6
		108·0	1·00	144·0

ES (ENGLISH).

r cubic inch

r cubic yard

r cubic yard

c foot

bic foot

bic foot

bic yard

bic metre

TABLE 42.—SQUARE INCHES IN DECIMAL FRACTIONS OF A SQUARE FOOT.

Square Inches.	Square Foot.	Square Inches.	Square Foot.	Square Inches.	Square Foot.	Square Inches.	Square Foot.
·10	·000694$\dot{4}$	**24**	·1666$\dot{6}$	**65**	·4513$\dot{8}$	**105**	·7291$\dot{6}$
·15	·001041$\dot{6}$	**25**	·1736$\dot{1}$	**66**	·45833	**106**	·7361$\dot{1}$
·20	·00138$\dot{8}$	**26**	·1805$\dot{5}$	**67**	·4652$\dot{7}$	**107**	·74305
·25	·001736$\dot{1}$	**27**	·18750	**68**	·4722$\dot{2}$	**108**	·75000
·30	·00208$\dot{3}$	**28**	·1944$\dot{4}$	**69**	·4791$\dot{6}$	**109**	·7569$\dot{4}$
·35	·002430$\dot{5}$	**29**	·2013$\dot{8}$	**70**	·4861$\dot{1}$	**110**	·7638$\dot{8}$
·40	·00277$\dot{7}$	**30**	·2083$\dot{3}$	**71**	·49305	**111**	·7708$\dot{3}$
·45	·0031124$\dot{9}$	**31**	·2152$\dot{7}$	**72**	·50000	**112**	·7777$\dot{7}$
·50	·00347$\dot{2}$	**32**	·2222$\dot{2}$	**73**	·5069$\dot{4}$	**113**	·7847$\dot{2}$
·55	·003819$\dot{4}$	**33**	·2291$\dot{6}$	**74**	·5138$\dot{8}$	**114**	·79166
·60	·00416$\dot{6}$	**34**	·2361$\dot{1}$	**75**	·5208$\dot{3}$	**115**	·7986$\dot{1}$
·65	·004513$\dot{8}$	**35**	·2430$\dot{5}$	**76**	·5277$\dot{7}$	**116**	·8055$\dot{5}$
·70	·00486$\dot{1}$	**36**	·25000	**77**	·53472	**117**	·8124$\dot{9}$
·75	·005208$\dot{3}$	**37**	·2569$\dot{4}$	**78**	·5416$\dot{6}$	**118**	·8194$\dot{4}$
·80	·00555$\dot{5}$	**38**	·2638$\dot{8}$	**79**	·54861	**119**	·8263$\dot{8}$
·85	·005902$\dot{7}$	**39**	·2708$\dot{3}$	**80**	·5555$\dot{5}$	**120**	·83333
·90	·006250	**40**	·2777$\dot{7}$	**81**	·56249	**121**	·8402$\dot{7}$
·95	·006597$\dot{2}$	**41**	·2847$\dot{2}$	**82**	·56944	**122**	·8472$\dot{2}$
1	·00694$\dot{4}$	**42**	·2916$\dot{6}$	**83**	·57638	**123**	·8541$\dot{6}$
2	·0138$\dot{8}$	**43**	·2986$\dot{1}$	**84**	·5833$\dot{3}$	**124**	·8611$\dot{1}$
3	·0208$\dot{3}$	**44**	·30555	**85**	·5902$\dot{7}$	**125**	·8680$\dot{5}$
4	·0277$\dot{7}$	**45**	·3124$\dot{9}$	**86**	·5972$\dot{2}$	**126**	·87500
5	·0347$\dot{2}$	**46**	·3194$\dot{4}$	**87**	·60416	**127**	·8819$\dot{4}$
6	·0416$\dot{6}$	**47**	·3263$\dot{8}$	**88**	·6111$\dot{1}$	**128**	·8888$\dot{8}$
7	·0486$\dot{1}$	**48**	·3333$\dot{3}$	**89**	·61805	**129**	·8958$\dot{3}$
8	·0555$\dot{5}$	**49**	·3402$\dot{7}$	**90**	·62500	**130**	·9027$\dot{7}$
9	·06250	**50**	·3472$\dot{2}$	**91**	·6319$\dot{4}$	**131**	·9097$\dot{2}$
10	·0694$\dot{4}$	**51**	·3541$\dot{6}$	**92**	·6388$\dot{8}$	**132**	·9166$\dot{6}$
11	·07638	**52**	·3611$\dot{1}$	**93**	·6458$\dot{3}$	**133**	·9236$\dot{1}$
12	·0833$\dot{3}$	**53**	·36805	**94**	·65277	**134**	·9305$\dot{5}$
13	·0902$\dot{7}$	**54**	·37500	**95**	·6597$\dot{2}$	**135**	·93750
14	·0972$\dot{2}$	**55**	·3819$\dot{4}$	**96**	·6666$\dot{6}$	**136**	·9444$\dot{4}$
15	·10416	**56**	·3888$\dot{8}$	**97**	·6736$\dot{1}$	**137**	·95138
16	·1111$\dot{1}$	**57**	·3958$\dot{3}$	**98**	·6805$\dot{5}$	**138**	·9583$\dot{3}$
17	·1180$\dot{5}$	**58**	·4027$\dot{7}$	**99**	·68750	**139**	·9652$\dot{7}$
18	·12500	**59**	·4097$\dot{2}$	**100**	·6944$\dot{4}$	**140**	·9722$\dot{2}$
19	·1319$\dot{4}$	**60**	·41666	**101**	·7013$\dot{8}$	**141**	·9791$\dot{6}$
20	·1388$\dot{8}$	**61**	·4236$\dot{1}$	**102**	·7083$\dot{3}$	**142**	·9861$\dot{1}$
21	·1458$\dot{3}$	**62**	·4305$\dot{5}$	**103**	·71527	**143**	·9930$\dot{5}$
22	·1527$\dot{7}$	**63**	·43750	**104**	·7222$\dot{2}$	**144**	1·00000
23	·1597$\dot{2}$	**64**	·4444$\dot{4}$				

TABLE 43.—DECIMAL FRACTIONS OF A SQUARE FOOT IN SQUARE INCHES.

Square Foot.	Square Inches.	Square Foot.	Square Inches.	Square Foot.	Square Inches.	Square Foot.	Square Inches.
·01	1·44	·26	37·4	·51	73·4	·76	109·4
·02	2·88	·27	38·9	·52	74·9	·77	110·9
·03	4·32	·28	40·3	·53	76·3	·78	112·3
·04	5·76	·29	41·8	·54	77·8	·79	113·8
·05	7·20	·30	43·2	·55	79·2	·80	115·2
·06	8·64	·31	44·6	·56	80·6	·81	116·6
·07	10·1	·32	46·1	·57	82·1	·82	118·1
·08	11·5	·33	47·5	·58	83·5	·83	119·5
·09	13·0	·34	49·0	·59	85·0	·84	121·0
·10	14·4	·35	50·4	·60	86·4	·85	122·4
·11	15·8	·36	51·8	·61	87·8	·86	123·8
·12	17·3	·37	53·3	·62	89·3	·87	125·3
·13	18·7	·38	54·7	·63	90·7	·88	126·7
·14	20·2	·39	56·2	·64	92·2	·89	128·2
·15	21·6	·40	57·6	·65	93·6	·90	129·6
·16	23·0	·41	58·0	·66	95·0	·91	131·0
·17	24·5	·42	60·5	·67	96·5	·92	132·5
·18	25·9	·43	61·9	·68	97·9	·93	133·9
·19	27·4	·44	63·4	·69	99·4	·94	135·4
·20	28·8	·45	64·8	·70	100·8	·95	136·8
·21	30·2	·46	66·2	·71	102·2	·96	138·2
·22	31·7	·47	67·7	·72	103·7	·97	139·7
·23	33·1	·48	69·1	·73	105·1	·98	141·1
·24	34·6	·49	70·6	·74	106·6	·99	142·6
·25	36·0	·50	72·0	·75	108·0	1·00	144·0

TABLE 44.—CORRELATIVE RATES (ENGLISH).

100 lbs. per cubic foot . . .	·926 ounce per cubic inch. 24·107 cwt. per cubic yard. 1·2053 tons per cubic yard.
1 cwt. per cubic yard	4·148 lbs. per cubic foot.
1 ton per cubic yard . .	82·963 lbs. per cubic foot.
1 grain per gallon (1 in 70,000 parts, by weight, of water)	6·2321 grains per cubic foot. 168·36 grains per cubic yard. 220·09 grains per cubic metre.
1 lb. per lineal yard . .	·7857 ton per mile.

TABLE 44.—CORRELATIVE RATES (ENGLISH)—(*continued*).

1 lb. per square inch . .	144 lbs. per square foot. 1296 lbs. per square yard. ·5786 ton per square yard. 2·0355 inches of mercury at 32° F. 2·0416 inches of mercury at 62° F. 2·309 feet of water at 62° F. 27·71 inches of water at 62° F.
1 atmosphere (14·7 lbs. per square inch)	2116·4 lbs. per square foot. 8·503 tons per square yard. 33·947 feet of water at 62° F. 10·347 metres of water at 62° F. 30 inches of mercury at 62° F.
1 lb. per square foot . .	·00694 lb. per square inch. ·1111 ounce per square inch. ·0804 cwt. per square yard.
1 inch of water at 62° F. .	·5773 ounce per square inch. ·0361 lb. per square inch. 5·20 lbs. per square foot. ·0736 inch of mercury at 62° F.
1 foot of water at 62° F. .	·433 lb. per square inch. 62·355 lbs. per square foot. ·883 inch of mercury at 62° F.
1 inch of mercury at 62° F. .	·49 lb. per square inch. 70·56 lbs. per square foot. 1·165 feet of water at 62° F. 14 inches of water at 62° F.
1 cubic foot per second .	2·222 cubic yards per minute. 133·333 cubic yards per hour.
1 cubic foot per minute .	2·222 cubic yards per hour.
·45 cubic foot per minute .	1 cubic yard per hour.
1 cubic inch per second .	2·083 cubic feet per hour. 12·984 gallons per hour.
1 mile per hour . . .	1·467 feet per second. 88 feet per minute.
1 foot per second . . .	·682 mile per hour.
1 foot per minute . . .	·01136 mile per hour. ·20 inch per second.
1 inch per second . .	5 feet per minute.

TABLE 45.—WATER.

1 Imperial gallon . . .	277·274 cubic inches.
	·1604 cubic foot.
	10 pounds of water at 62° F.
	70,000 grains of water at 62° F
	1·20 U.S. gallons.
	4·544 litres.
1 U. S. gallon . . .	231 cubic inches.
	·1337 cubic foot.
	8·333 pounds of water at 62° F.
	·8333 imperial gallon (⅚ths).
	3·786 litres.
1 cubic inch of water at 62° F.	·03608 pound.
	·5773 ounce.
	252·6 grains.
	·003607 imperial gallon.
	·004326 U.S. gallon.
	·01638 litre.
1 cubic foot of water at 62° F.	62·355 pounds.
	997·68 ounces (about 1000).
	·557 cwt.
	·0278 ton.
	6·2355 imperial gallons.
	49·884 imperial pints (about 50).
	7·4805 U.S. gallons.
	28·315 litres.
	·02832 cubic metre.
1 cylindrical inch of water at 62° F.	·02833 pound.
	·4533 ounce.
	·7854 cubic inch.
1 cylindrical foot of water at 62° F.	48·973 pounds (about 50).
	783·57 ounces.
	·437 cwt.
	·0219 ton.
	4·8973 imperial gallons.
	5·8758 U.S. gallons.
	22·2380 litres.
	·02224 cubic metre.
1 cubic yard of water . .	1684·8 pounds.
	15·043 cwt., or 15 cwt. 4·8 pounds.
	·7645 cubic metre.
1 litre of water . . .	2·2046 pounds at 62° F.
	·2201 imperial gallon.
	1·761 imperial pint.
	·2641 U.S. gallon.
	61·025 cubic inches.
	·0353 cubic foot.

TABLE 45.—WATER (*continued*).

1 cubic metre of water .	1 tonne, or 1000 kilogrammes at 39·1° F. or 4° C.
	2204·62 pounds at 39·1° F. or 4° C.
	2203·7 pounds at 62·4 pounds per cubic foot.
	1 ton of 2240 pounds, nearly.
	1 tun of 4 hogsheads or 2100 pounds, nearly.
	220·1 imperial gallons.
	264·2 U.S. gallons.
	1·308 cubic yards.
	35·3156 cubic feet.
	1000 litres.

The weight of fresh water is commonly assumed, in ordinary calculations, to be 62·4 pounds per cubic foot, which is the weight at 52·3° F. It is frequently taken as 62½ pounds or 1000 ounces per cubic foot.

The volumes of given weights of water, at the rate of 62·4 pounds per cubic foot, are as follows :—

1 ton	35·90 cubic feet (about 36).
1 cwt.	1·795 "
1 pound	·016 " 27·692 cubic inches.
1 ounce	1·731 "
1 tonne, at 39·1° F. or 4° C. .	35·3156 cubic feet.
1 kilogramme " " .	·0353 " 61·025 cubic inches.
1 tonne, at 52·3° F. (62·4 pounds per cubic foot) . .	35·330 cubic feet.

A pipe 1 yard in length holds about as many pounds of water of ordinary temperatures as the square of its diameter in inches (about two per cent. more).

A column of water at 62° F. 1 foot high, is equivalent to a pressure of ·433 pound, or 6·928 ounces per square inch of base, or to 62·355 pounds per square foot.

A column of water 1 inch high is equivalent to a pressure of ·5773 ounce, or ·03608 pound per square inch; or to 5·196 pounds per square foot.

A column of water 100 feet high is equivalent to 43⅓ pounds per square inch; or 2·786 tons per square foot.

A column of water 1 mile deep, weighing 62·4 pounds per cubic foot, is equivalent to a pressure of about 1 ton per square inch.

1 pound per square inch is equivalent to a column of water at 62° F. 2·31 feet or 27·72 inches high.

Sea Water.

1 cubic foot at 62° F. . . .	64 pounds.
1 cubic yard	15½ cwt. nearly (8 pounds less).
1 cubic metre . . .	1 ton fully (20 pounds more).
1 ton	35 cubic feet.
Ratio of weight of fresh water to that of sea water . .	39 to 40, or 1 to 1·028.

Ice and Snow.

1 cubic foot of ice at 32° F.	57·50 pounds.
1 pound of ice „ „	·0174 cubic foot, or 30·067 cubic inches.

Specific density of ice, ·922 ; that of water at 62° F. being 1.

1 cubic foot of fresh snow, according to humidity of atmosphere : 5 pounds to 12 pounds (Trautwine).

1 cubic foot of snow moistened and compacted by rain . . .	15 pounds to 50 pounds (Trautwine).

TABLE 46.—AIR.

1 cubic foot, at 14·7 lbs. per square inch, or 1 atmosphere	·080728 pound at 32° F. 1·29 ounce „ „ 565·1 grains „ „ ·076097 pound at 62° F. 1·217 ounce „ „ 532·7 grains „ „
1 litre, under one atmosphere	1·293 grammes at 32° F. 19·955 grains „ „
1 pound of air at 62° F. .	13·141 cubic feet.

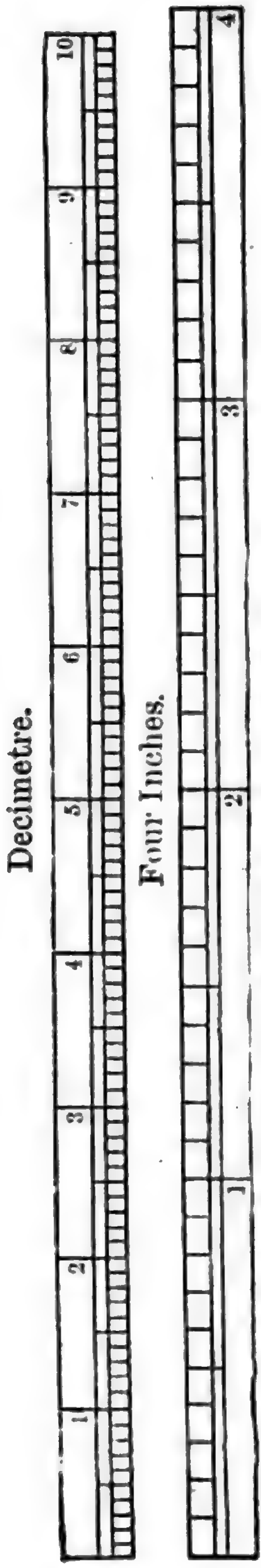
The weights of equal volumes of mercury, water and air at 62° F. under 1 atmosphere, are as 11140·56, 819·4 and 1.

1 atmosphere of pressure .	14·7 lbs. per square inch. 2116·4 lbs. per square foot. 1·0335 kilogrammes per square centimetre. 29·922 inches of mercury at 32° F. 76 centimetres of mercury at 32° F. 30 inches of mercury at 62° F. 33·947 feet of water at 62° F. 10·347 metres of water at 62° F.

TABLE 46.—AIR (*continued*).

1 lb. per square inch . .	2·035 inches of mercury at 32° F. 51·7 millimetres ” ” 2·04 inches of mercury at 62° F. 2·31 feet of water at 62° F. 27·72 inches ” ”
1 ounce per square inch .	1·732 inches ” ”
1 lb. per square foot . .	·1925 inch ” ” ·01417 inch of mercury at 62° F.

French Metric Weights and Measures.



FIGS. 17, 18.—French and English Measures compared.

The metre, equal to 39·37043 inches, and the kilogramme, equal to 2·20462 pounds, are the only standards of weight and measure in France. The kilogramme is defined as the weight of a cubic decimetre of distilled water at its maximum density, at 4·0° C., or 39·1° F. It is legally taken to be 2·20462125 pounds. The gramme, of which there are one thousand in the kilogramme, is the unit of weight. It is the weight of one cubic centimetre of water under the conditions above defined.

The metric unit of capacity is the litre, defined as equal to a cubic decimetre. It is equal to 0·22009 gallon.

The French metric system has been compulsorily adopted by France and Belgium in 1801; Holland in 1819; Greece in 1836; Italy and Spain, in 1859; Portugal in 1860—68; the German Empire, in 1872; Colombia, Venezuela, in 1872. The system is established in France and her Colonies, Belgium, Holland and her Colonies, Germany, Sweden, Norway, Austro-Hungary, Italy, Spain, Portugal, Turkey, Roumania, Greece, Brazil, Colombia, Uruguay, Ecuador, Peru, Chili, the Argentine Republic. It has been made legally optional in Great Britain and Ireland, the United States of North America and Canada. It is admitted in principle, or partially for customs, in British India, Russia, and Venezuela. Switzerland, in 1856, legalised the foot of three decimetres as the unit of length, with a decimal scale; with a unit of weight, the pound of 500 grammes, or half a kilogramme, with two distinct scales of multiples and parts, one decimal, the other on the old system. Denmark adopted the metric system so far as the pound of 500 grammes.

TABLE 47.—FRENCH MEASURES OF LENGTH.

		Metres.	English Equivalents.
	1 millimetre =	·001 =	·03937 in., or $\frac{1}{25}$ in. nearly.
10 millimetres	= 1 centimetre =	·01 =	·3937 inch.
10 centimetres	= 1 decimetre =	·1 =	3·93704 in., or 4 ins. nearly.
10 decimetres 100 centimetres 1000 millimetres	= 1 METRE =	1 =	39·3704 ins. 3·2809 feet.
10 metres	= 1 decametre =	10 =	32·8087 feet.
10 decametres	= 1 hectometre =	100 =	328·0869 feet. 109·3623 yds.
10 hectometres	= 1 KILOMETRE =	1000 =	3280·869 feet. 1093·623 yds. ·62138mle.
10 kilometres	= 1 myriametre =	10,000 =	6·21377 miles.

TABLE 48.—FRENCH MEASURES OF SURFACE.

		Sq. Metres.	English Equivalents.
	1 sq. millimetre	·000001	·00155 sq. in.
100 square millimetres	1 sq. centimetre .	·0001	·155 sq. in.
100 square centimetres.	1 sq. decimetre .	·01	15·5003 sq. ins.
100 square decimetres. 10,000 square centimetres.	1 square metre or centiare . .	1	10·7641 sq. ft. 1·1960 sq. yds.
100 square metres.	1 sq. decametre, or are . . .	100	1076·41 sq. ft. 119·601 sq. yds.
100 square decametres.	1 sq. hectometre or hectare, or metrical acre .	10,000	11,960·11 sq.yds. 2·4711 acres.
100 square hectometres.	1 sq. kilometre .	1,000,000	1,196,014 sq.yds. ·38611 sq. mile.
100 square kilometres.	1 sq. myriametre .	100,000,000 =	38·611 sq.miles

Land is measured in terms of the centiare, the are, and the hectare.

Wood (France).

The large pieces of timber, cut from the trees, are of the following ordinary squared sizes.

	Metre.	Inches.
Oak	·10 to ·30	3·94 to 11·8
Small stowage (*Petit arrimage*) .	·30 to ·40	11·8 to 15·7

	Metre.	Inches.
Large stowage (*Gros arrimage*)	·40 to ·60	15·7 to 23·6
Fir	·18 to ·27	7·1 to 10·6
do. beams	·27 to ·36	10·6 to 14·2
do. large wood	·36 to ·60	14·2 to 23·6

TABLE 49.—OAK SCANTLINGS IN COMMERCIAL USE (FRANCE).

Description.	Width.		Thickness.		Length.	
	Millimetres.	Inches.	Millimetres.	Inches.	Metres.	Feet.
Echantillon (sample)	25	·98	42	1·65	1·5 to 4	4·9 to 13·2
Membrure (frame)	167	6·57	83	3·27	2 to 4	6·6 to 13·2
Doublette (principal)	333	11·93	63	2·48	2·5 to 4	8·2 to 13·2
Grand Battant (large doorframe)	333	11·93	126	4·96	4 to 6	13·1 to 19·7
Petit Battant (small doorframe)	25	·98	83	3·27	3 to 6	9·8 to 19·7
Entrevous (between joists)	25	·98	28	1·10	1·5 to 4	4·9 to 13·2
Chevron (joist)	83	3·27	83	3·27	2 to 4	6·6 to 13·2
Membrette	167	6·57	56	2·20	1·5 to 4	4·9 to 13·2
Panneau (panel)	216 to 243	8·51 to 9·57	20 to 22	·79 to ·87	2 to 4	6·6 to 13·2
Volige (thin plank)	216 to 243	8·51 to 9·57	13 to 15	·51 to ·59	2 to 4	6·6 to 13·2
Feuillet (edge of panel)	216 to 243	8·51 to 9·57	6 to 7	·24 to ·28	2 to 4	6·6 to 13·2
FIR SCANTLINGS.						
Madrier (plank-principal piece)	220	8·66	80	3·15	...	...
Petit Madrier (smaller piece)	220	8·66	54	2·13	..	...
Planche (board)	220 or 320	8·66 or 12·60	27	1·06	...	...

TABLE 50.—FRENCH MEASURES OF VOLUME.

Cubic Measure.

		Cubic Metres.	English Equivalents.
	1 cubic millimetre	·000000001	·000061 cubic inch.
1000 cubic millimetres	1 cubic centimetre	·000001	·061025 cubic inch.
1000 cubic centimetres	1 cubic decimetre	·001	61·02524 cubic ins. ·0353156 cubic ft.
1000 cubic decimeters	1 cubic metre	1	35·3156 cubic feet. 1·308 cubic yards.
1000 cubic metres	1 cubic decametre	1,000	1308 cubic yards.

Firewood Measure (French).

		Cubic Metres.	
	1 decistère	0·1	3·532 cubic feet.
10 decistères	1 stère (cubic metre)	1	35·3156 cubic feet.
1 vois (Paris)	2 stères	2	70·6312 cubic feet.
1 vois de charbon (charcoal)	0·2 stère	0·2	7·063 cubic feet.
1 corde	4 stères	4	141·2624 ”
1 decastère	10 stères	10	353·156 ”

The stère measures 1·14 metres × 0·88 metre, by 1 metre, the billets being 1·14 metres in length.

Liquid Measure.

		Litres.	
	1 centilitre 10 cubic centimetres	·01	·61025 cubic inch. ·0704 gill.
10 centilitres	1 décilitre	0·1	6·1025 cubic inches. ·1761 pint.
10 décilitres	1 LITRE (1 cubic decimetre)	1	61·02524 cubic ins. ·2201 gallon.
10 litres	1 décalitre	10	2·2009 gallons.
10 décalitres	1 hectolitre	100	22·009 gallons.

Dry Measure.

10 litres	1 décalitre	10	2·2009 gallons.
10 décalitres	1 hectolitre	100	22·009 gallons. 2·7511 bushels.
10 hectolitres	1 kilolitre. (1 cubic metre)	1000	220·09 gallons. 27·511 bushels.

The use of measures equal to a *double-litre*, a *half-litre*, a *double-décilitre*, a *half-décilitre*, is sanctioned by law.

TABLE 51.—FRENCH MEASURES OF WEIGHT.

		Grammes.	English Equivalents.
	1 milligramme	·001	·0154 grain.
10 milligrammes	1 centigramme	·01	·1543 grain.
10 centigrammes	1 decigramme	0·1	1·5432 grains.
10 decigrammes	1 GRAMME (unit of weight)	1	15·4323 grains.
10 grammes	1 décagramme	10	154·3235 grains. ·3527 ounce.
10 décagrammes	1 hectogramme	100	1543·2349 grains. 3·5274 ounces.
10 hectogrammes	1 KILOGRAMME	1000	2·2046 pounds.
100 kilogrammes	1 metric quintal		220·4621 pounds.
10 quintals, or 1000 kilogrammes	1 millier, or tonne		2204·6212 pounds. 19·6841 cwts. ·9842 ton.

TABLE 52.—MILLIMETRES IN LINEAL INCHES.

Millimetres.	Inches.	Millimetres.	Inches.	Millimetres.	Inches.	Millimetres.	Inches.
1	·0394	**26**	1·0236	**51**	2·0079	**76**	2·9922
2	·0787	**27**	1·0630	**52**	2·0473	**77**	3·0315
3	·1181	**28**	1·1024	**53**	2·0866	**78**	3·0709
4	·1575	**29**	1·1417	**54**	2·1260	**79**	3·1103
5	·1968	**30**	1·1811	**55**	2·1654	**80**	3·1496
6	·2362	**31**	1·2205	**56**	2·2047	**81**	3·1890
7	·2756	**32**	1·2598	**57**	2·2441	**82**	3·2284
8	·3150	**33**	1·2992	**58**	2·2835	**83**	3·2677
9	·3543	**34**	1·3386	**59**	2·3228	**84**	3·3071
10	·3937	**35**	1·3780	**60**	2·3622	**85**	3·3465
11	·4331	**36**	1·4173	**61**	2·4016	**86**	3·3859
12	·4724	**37**	1·4567	**62**	2·4410	**87**	3·4252
13	·5118	**38**	1·4961	**63**	2·4803	**88**	3·4646
14	·5512	**39**	1·5354	**64**	2·5197	**89**	3·5040
15	·5906	**40**	1·5748	**65**	2·5591	**90**	3·5433
16	·6299	**41**	1·6142	**66**	2·5984	**91**	3·5827
17	·6693	**42**	1·6536	**67**	2·6378	**92**	3·6221
18	·7087	**43**	1·6929	**68**	2·6772	**93**	3·6614
19	·7480	**44**	1·7323	**69**	2·7166	**94**	3·7008
20	·7874	**45**	1·7717	**70**	2·7559	**95**	3·7402
21	·8268	**46**	1·8110	**71**	2·7953	**96**	3·7796
22	·8661	**47**	1·8504	**72**	2·8347	**97**	3·8189
23	·9055	**48**	1·8898	**73**	2·8740	**98**	3·8583
24	·9449	**49**	1·9291	**74**	2·9134	**99**	3·8977
25	·9843	**50**	1·9685	**75**	2·9528	**100**	3·9370

TABLE 52.—MILLIMETRES IN LINEAL INCHES (*continue*

Milli-metres.	Inches.	Milli-metres.	Inches.	Milli-metres.	Inches.	Milli-metres.	Inches.
101	3·9764	**143**	5·6300	**185**	7·2835	**227**	8·9371
102	4·0158	**144**	5·6693	**186**	7·3229	**228**	8·9765
103	4·0552	**145**	5·7087	**187**	7·3623	**229**	9·0158
104	4·0945	**146**	5·7481	**188**	7·4016	**230**	9·0552
105	4·1339	**147**	5·7874	**189**	7·4410	**231**	9·0946
106	4·1733	**148**	5·8268	**190**	7·4804	**232**	9·1339
107	4·2126	**149**	5·8662	**191**	7·5198	**233**	9·1733
108	4·2520	**150**	5·9056	**192**	7·5591	**234**	9·2127
109	4·2914	**151**	5·9449	**193**	7·5985	**235**	9·2521
110	4·3307	**152**	5·9843	**194**	7·6379	**236**	9·2914
111	4·3701	**153**	6·0237	**195**	7·6772	**237**	9·3308
112	4·4095	**154**	6·0630	**196**	7·7166	**238**	9·3702
113	4·4489	**155**	6·1024	**197**	7·7560	**239**	9·4095
114	4·4882	**156**	6·1418	**198**	7·7954	**240**	9·4489
115	4·5276	**157**	6·1812	**199**	7·8347	**241**	9·4883
116	4·5670	**158**	6·2205	**200**	7·8741	**242**	9·5277
117	4·6063	**159**	6·2599	**201**	7·9135	**243**	9·5670
118	4·6457	**160**	6·2993	**202**	7·9528	**244**	9·6064
119	4·6851	**161**	6·3386	**203**	7·9922	**245**	9·6458
120	4·7245	**162**	6·3780	**204**	8·0316	**246**	9·6851
121	4·7638	**163**	6·4174	**205**	8·0709	**247**	9·7245
122	4·8032	**164**	6·4568	**206**	8·1103	**248**	9·7639
123	4·8426	**165**	6·4961	**207**	8·1497	**249**	9·8032
124	4·8819	**166**	6·5355	**208**	8·1891	**250**	9·8426
125	4·9213	**167**	6·5749	**209**	8·2284	**251**	9·8820
126	4·9607	**168**	6·6142	**210**	8·2678	**252**	9·9214
127	5·0000	**169**	6·6536	**211**	8·3072	**253**	9·9607
128	5·0394	**170**	6·6930	**212**	8·3465	**254**	10·0001
129	5·0788	**171**	6·7323	**213**	8·3859	**255**	10·0395
130	5·1182	**172**	6·7717	**214**	8·4253	**256**	10·0788
131	5·1575	**173**	6·8111	**215**	8·4646	**257**	10·1182
132	5·1969	**174**	6·8505	**216**	8·5040	**258**	10·1576
133	5·2363	**175**	6·8898	**217**	8·5434	**259**	10·1970
134	5·2756	**176**	6·9292	**218**	8·5828	**260**	10·2363
135	5·3150	**177**	6·9686	**219**	8·6221	**261**	10·2757
136	5·3544	**178**	7·0079	**220**	8·6615	**262**	10·3151
137	5·3938	**179**	7·0473	**221**	8·7009	**263**	10·3544
138	5·4331	**180**	7·0867	**222**	8·7402	**264**	10·3938
139	5·4725	**181**	7·1261	**223**	8·7796	**265**	10·4332
140	5·5119	**182**	7·1654	**224**	8·8190	**266**	10·4725
141	5·5512	**183**	7·2048	**225**	8·8584	**267**	10·5119
142	5·5906	**184**	7·2442	**226**	8·8977	**268**	10·5513

ABLE 52.—MILLIMETRES IN LINEAL INCHES (*continued*).

Milli-etres.	Inches.	Milli-metres.	Inches.	Milli-metres.	Inches.	Milli-metres.	Inches.
269	10·5907	**311**	12·2442	**353**	13·8978	**395**	15·5513
270	10·6300	**312**	12·2836	**354**	13·9371	**396**	15·5907
271	10·6694	**313**	12·3229	**355**	13·9765	**397**	15·6300
272	10·7088	**314**	12·3623	**356**	14·0159	**398**	15·6694
273	10·7481	**315**	12·4017	**357**	14·0552	**399**	15·7088
274	10·7875	**316**	12·4410	**358**	14·0946	**400**	15·7482
275	10·8269	**317**	12·4804	**359**	14·1340	**401**	15·7875
276	10·8663	**318**	12·5198	**360**	14·1733	**402**	15·8269
277	10·9056	**319**	12·5592	**361**	14·2127	**403**	15·8663
278	10·9450	**320**	12·5985	**362**	14·2521	**404**	15·9056
279	10·9844	**321**	12·6379	**363**	14·2915	**405**	15·9450
280	11·0237	**322**	12·6773	**364**	14·3308	**406**	15·9844
281	11·0361	**323**	12·7166	**365**	14·3702	**407**	16·0238
282	11·1025	**324**	12·7560	**366**	14·4096	**408**	16·0631
283	11·1419	**325**	12·7954	**367**	14·4489	**409**	16·1025
284	11·1812	**326**	12·8348	**368**	14·4883	**410**	16·1419
285	11·2206	**327**	12·8741	**369**	14·5277	**411**	16·1812
286	11·2600	**328**	12·9135	**370**	14·5670	**412**	16·2206
287	11·2993	**329**	12·9529	**371**	14·6064	**413**	16·2600
288	11·3387	**330**	12·9922	**372**	14·6458	**414**	16·2993
289	11·3781	**331**	13·0316	**373**	14·6852	**415**	16·3387
290	11·4174	**332**	13·0710	**374**	14·7245	**416**	16·3781
291	11·4568	**333**	13·1103	**375**	14·7639	**417**	16·4175
292	11·4962	**334**	13·1497	**376**	14·8033	**418**	16·4568
293	11·5356	**335**	13·1891	**377**	14·8426	**419**	16·4962
294	11·5749	**336**	13·2285	**378**	14·8820	**420**	16·5356
295	11·6143	**337**	13·2678	**379**	14·9214	**421**	16·5749
296	11·6537	**338**	13·3072	**380**	14·9608	**422**	16·6143
297	11·6930	**339**	13·3466	**381**	15·0001	**423**	16·6537
298	11·7324	**340**	13·3859	**382**	15·0395	**424**	16·6930
299	11·7718	**341**	13·4253	**383**	15·0789	**425**	16·7324
300	11·8111	**342**	13·4647	**384**	15·1182	**426**	16·7718
301	11·8505	**343**	13·5040	**385**	15·1576	**427**	16·8112
302	11·8899	**344**	13·5434	**386**	15·1970	**428**	16·8505
303	11·9292	**345**	13·5828	**387**	15·2363	**429**	16·8899
304	11·9686	**346**	13·6222	**388**	15·2757	**430**	16·9293
305	12·0080	**347**	13·6615	**389**	15·3151	**431**	16·9686
306	12·0473	**348**	13·7009	**390**	15·3545	**432**	17·0080
307	12·0867	**349**	13·7403	**391**	15·3938	**433**	17·0474
308	12·1261	**350**	13·7790	**392**	15·4332	**434**	17·0868
309	12·1655	**351**	13·8190	**393**	15·4726	**435**	17·1261
310	12·2048	**352**	13·8584	**394**	15·5119	**436**	17·1655

TABLE 52.—MILLIMETRES IN LINEAL INCHES (*continued*).

Milli-metres.	Inches.	Milli-metres	Inches.	Milli-metres.	Inches.	Milli-metres.	Inches.
437	17·2049	**456**	17·9529	**475**	18·7009	**494**	19·4490
438	17·2442	**457**	17·9923	**476**	18·7403	**495**	19·4883
439	17·2836	**458**	18·0316	**477**	18·7797	**496**	19·5277
440	17·3230	**459**	18·0710	**478**	18·8191	**497**	19·5671
441	17·3623	**460**	18·1104	**479**	18·8584	**498**	19·6065
442	17·4017	**461**	18·1498	**480**	18·8978	**499**	19·6458
443	17·4411	**462**	18·1891	**481**	18·9372	**500**	19·6852
444	17·4805	**463**	18·2285	**482**	18·9765	**550**	21·6537
445	17·5198	**464**	18·2679	**483**	19·0159	**600**	23·6223
446	17·5592	**465**	18·3072	**484**	19·0553	**650**	25·5908
447	17·5986	**466**	18·3466	**485**	19·0946	**700**	27·5593
448	17·6379	**467**	18·3860	**486**	19·1340	**750**	29·5278
449	17·6773	**468**	18·4253	**487**	19·1734	**800**	31·4963
450	17·7167	**469**	18·4647	**488**	19·2128	**850**	33·4649
451	17·7561	**470**	18·5041	**489**	19·2521	**900**	35·4334
452	17·7954	**471**	18·5435	**490**	19·2915	**950**	37·4019
453	17·8350	**472**	18·5828	**491**	19·3309	**1000**	39·3704
454	17·8742	**473**	18·6222	**492**	19·3702		= 1
455	17·9135	**474**	18·6615	**493**	19·4096		metre.

By means of the above Table, and the following Table 53, the equivalent values of inches in centimetres and decimetres, and even in metres, may be found by simply altering the position of the decimal point. Take for example the tabular value of 2 millimetres, Table 52, and shift the decimal point successively, by one digit, towards the right-hand side; the values of two centimetres, two decimetres, and two metres are thereby expressed in inches, as follows:—

2 millimetres	·0787	inches.
2 centimetres	0·787	„
2 decimetres	7·87	„
2 metres	78·7	„

At the same time, it appears that, by selecting the tabular value of 20 millimetres, the value of its multiples are given more accurately, thus,—

20 millimetres, or 2 centimetres .	0·7874	inches.
2 decimetres	7·874	„
2 metres	78·74	„

Again :—

200 millimetres, or 2 decimetres = 7·8741 inches
2 metres . . . . . . = 78·741 ,,

Similarly, for example :—

·32 inch = 8·128 millimetres.
3·2 ,, = 81·28 ,,
32·0 ,, = { 812·8 ,, or
·8128 metre.

Like functional expansions of the following tables of relative French and English measures and weight, are available for practice : greatly extending the utility of the tables.

TABLE 53.—DECIMAL FRACTIONS OF A LINEAL INCH IN MILLIMETRES.

Inch.	Millimetres.	Inch.	Millimetres.	Inch.	Millimetres.	Inches.	Millimetres.
·01	·254	**·29**	7·366	**·57**	14·478	**·85**	21·590
·02	·508	**·30**	7·620	**·58**	14·732	**·86**	21·844
·03	·762	**·31**	7·874	**·59**	14·986	**·87**	22·098
·04	1·016	**·32**	8·128	**·60**	15·240	**·88**	22·352
·05	1·270	**·33**	8·382	**·61**	15·494	**·89**	22·606
·06	1·524	**·34**	8·636	**·62**	15·748	**·90**	22·860
·07	1·778	**·35**	8·890	**·63**	16·002	**·91**	23·114
·08	2·032	**·36**	9·144	**·64**	16·256	**·92**	23·368
·09	2·286	**·37**	9·398	**·65**	16·510	**·93**	23·622
·10	2·540	**·38**	9·652	**·66**	16·764	**·94**	23·876
·11	2·794	**·39**	9·906	**·67**	17·018	**·95**	24·130
·12	3·048	**·40**	10·160	**·68**	17·272	**·96**	24·384
·13	3·302	**·41**	10·414	**·69**	17·526	**·97**	24·638
·14	3·556	**·42**	10·668	**·70**	17·780	**·98**	24·892
·15	3·810	**·43**	10·922	**·71**	18·034	**·99**	25·146
·16	4·064	**·44**	11·176	**·72**	18·288	**1·00**	25·400
·17	4·318	**·45**	11·430	**·73**	18·542	**2·00**	50·799
·18	4·572	**·46**	11·684	**·74**	18·796	**3·00**	76·199
·19	4·826	**·47**	11·938	**·75**	19·050	**4·00**	101·598
·20	5·080	**·48**	12·192	**·76**	19·304	**5·00**	126·998
·21	5·334	**·49**	12·446	**·77**	19·558	**6·00**	152·397
·22	5·588	**·50**	12·700	**·78**	19·812	**7·00**	177·797
·23	5·842	**·51**	12·954	**·79**	20·066	**8·00**	203·196
·24	6·096	**·52**	13·208	**·80**	20·320	**9·00**	228·596
·25	6·350	**·53**	13·462	**·81**	20·574	**10·00**	253·995
·26	6·604	**·54**	13·716	**·82**	20·828	**11·00**	279·395
·27	6·858	**·55**	13·970	**·83**	21·082	**12·00** =1 foot	304·794
·28	7·112	**·56**	14·224	**·84**	21·336		

TABLE 54.—VULGAR FRACTIONS OF A LINEAL INCH IN MILLIMETRES.

Eighths of an Inch.	Millimetres.	Eighths of an Inch.	Millimetres.	Eighths of an Inch.	Millimetres.
1	3·175	4	12·700	7	22·225
2	6·350	5	15·875	8	25·400
3	9·525	6	19·050		

Twelfths of an Inch.	Millimetres.	Twelfths of an Inch.	Millimetres.	Twelfths of an Inch.	Millimetres.
1	2·117	5	10·583	9	19·050
2	4·233	6	12·700	10	21·166
3	6·350	7	14·816	11	23·283
4	8·466	8	16·933	12	25·400

Sixteenths of an Inch.	Millimetres.	Sixteenths of an Inch.	Millimetres.	Sixteenths of an Inch.	Millimetres.
1	1·587	7	11·112	13	20·637
3	4·762	9	14·287	15	23·812
5	7·937	11	17·462		

Thirty-seconds of an Inch.	Millimetres.	Thirty-seconds of an Inch.	Millimetres.	Thirty-seconds of an Inch.	Millimetres.
1	0·794	13	10·319	25	19·843
3	2·381	15	11·906	27	21·431
5	3·969	17	13·493	29	23·018
7	5·556	19	15·081	31	24·606
9	7·144	21	16·668		
11	8·731	23	18·256		

Sixty-fourths of an Inch.	Millimetres.	Sixty-fourths of an Inch.	Millimetres.	Sixty-fourths of an Inch.	Millimetres.
1	0·397	23	9·128	45	17·859
3	1·191	25	9·922	47	18·653
5	1·984	27	10·715	49	19·447
7	2·778	29	11·509	51	20·240
9	3·572	31	12·303	53	21·034
11	4·366	33	13·097	55	21·828
13	5·159	35	13·890	57	22·621
15	5·953	37	14·684	59	23·415
17	6·747	39	15·478	61	24·209
19	7·540	41	16·272	63	25·003
21	8·334	43	17·065		

TABLE 55.—METRES IN LINEAL FEET AND IN YARDS.

Metres.	Feet.	Yards.	Metres.	Feet.	Yards.
1	3·2809	1·0936	**44**	144·3596	48·1193
2	6·5618	2·1872	**45**	147·6405	49·2129
3	9·8427	3·2809	**46**	150·9214	50·3065
4	13·1236	4·3745	**47**	154·2023	51·4001
5	16·4045	5·4681	**48**	157·4832	52·4938
6	19·6854	6·5617	**49**	160·7641	53·5874
7	22·9663	7·6553	**50**	164·0450	54·6810
8	26·2472	8·7490	**51**	167·3259	55·7746
9	29·5281	9·8426	**52**	170·6068	56·8682
10	32·8090	10·9362	**53**	173·8877	57·9619
11	36·0899	12·0298	**54**	177·1686	59·0555
12	39·3708	13·1234	**55**	180·4495	60·1491
13	42·6517	14·2171	**56**	183·7304	61·2427
14	45·9326	15·3107	**57**	187·0113	62·3363
15	49·2135	16·4043	**58**	190·2922	63·4300
16	52·4944	17·4979	**59**	193·5731	64·5236
17	55·7753	18·5915	**60**	196·8540	65·6172
18	59·0562	19·6852	**61**	200·1349	66·7108
19	62·3371	20·7788	**62**	203·4158	67·8044
20	65·6180	21·8724	**63**	206·6967	68·8981
21	68·8989	23·9660	**64**	209·9776	69·9917
22	72·1798	24·0596	**65**	213·2585	71·0853
23	75·4607	25·1533	**66**	216·5394	72·1789
24	78·7416	26·2469	**67**	219·8203	73·2725
25	82·0225	27·3405	**68**	223·1012	74·3662
26	85·3034	28·4341	**69**	226·3821	75·4598
27	88·5843	29·5277	**70**	229·6630	76·5534
28	91·8652	30·6214	**71**	232·9439	77·6470
29	95·1461	31·7150	**72**	236·2248	78·7406
30	98·4270	32·8086	**73**	239·5057	79·8343
31	101·7079	33·9022	**74**	242·7866	80·9279
32	104·9888	34·9958	**75**	246·0675	82·0215
33	108·2697	36·0895	**76**	249·3484	83·1151
34	111·5506	37·1831	**77**	252·6293	84·2087
35	114·8315	38·2767	**78**	255·9102	85·3024
36	118·1124	39·3703	**79**	259·1911	86·3960
37	121·3933	40·4639	**80**	262·4720	87·4896
38	124·6742	41·5576	**81**	265·7529	88·5832
39	127·9551	42·6512	**82**	269·0338	89·6768
40	131·2360	43·7448	**83**	272·3147	90·7705
41	134·5169	44·8384	**84**	275·5956	91·8641
42	137·7978	45·9320	**85**	278·8765	92·9577
43	141·0787	47·0257	**86**	282·1574	94·0513

TABLE 55.—METRES IN LINEAL FEET AND IN YARDS (*continued*).

Metres.	Feet.	Yards.	Metres.	Feet.	Yards.
87	285·4383	95·1449	**94**	308·4046	102·8003
88	288·7192	96·2386	**95**	311·6855	103·8939
89	292·0001	97·3322	**96**	314·9664	104·9875
90	295·2810	98·4258	**97**	318·2473	106·0811
91	298·5619	99·5194	**98**	321·5282	107·1748
92	301·8428	100·6130	**99**	324·8091	108·2684
93	305·1237	101·7067	**100**	328·0900	109·3620

TABLE 56.—LINEAL FEET IN METRES.

Feet.	Metres.	Feet.	Metres.	Feet.	Metres.	Feet.	Metres.
1	·3048	**26**	7·9248	**51**	15·5448	**76**	23·1648
2	·6096	**27**	8·2296	**52**	15·8496	**77**	23·4696
3	·9144	**28**	8·5344	**53**	16·1544	**78**	23·7744
4	1·2192	**29**	8·8392	**54**	16·4592	**79**	24·0792
5	1·5240	**30**	9·1440	**55**	16·7640	**80**	24·3840
6	1·8288	**31**	9·4488	**56**	17·0688	**81**	24·6888
7	2·1336	**32**	9·7536	**57**	17·3736	**82**	24·9936
8	2·4384	**33**	10·0584	**58**	17·6784	**83**	25·2984
9	2·7432	**34**	10·3632	**59**	17·9832	**84**	25·6032
10	3·0480	**35**	10·6680	**60**	18·2880	**85**	25·9080
11	3·3528	**36**	10·9728	**61**	18·5928	**86**	26·2128
12	3·6576	**37**	11·2776	**62**	18·8976	**87**	26·5176
13	3·9624	**38**	11·5824	**63**	19·2024	**88**	26·8224
14	4·2672	**39**	11·8872	**64**	19·5072	**89**	27·1272
15	4·5720	**40**	12·1920	**65**	19·8120	**90**	27·4320
16	4·8768	**41**	12·4968	**66**	20·1168	**91**	27·7368
17	5·1816	**42**	12·8016	**67**	20·4216	**92**	28·0416
18	5·4864	**43**	13·1064	**68**	20·7264	**93**	28·3464
19	5·7912	**44**	13·4112	**69**	21·0312	**94**	28·6512
20	6·0960	**45**	13·7160	**70**	21·3360	**95**	28·9560
21	6·4008	**46**	14·0208	**71**	21·6408	**96**	29·2608
22	6·7056	**47**	14·3256	**72**	21·9456	**97**	29·5656
23	7·0104	**48**	14·6304	**73**	22·2504	**98**	29·8704
24	7·3152	**49**	14·9352	**74**	22·5552	**99**	30·1752
25	7·6200	**50**	15·2400	**75**	22·8600	**100**	30·4800

TABLE 57.—LINEAL YARDS IN METRES.

Yards.	Metres.	Yards.	Metres.	Yards.	Metres.	Yards.	Metres.
1	·9144	26	23·7741	51	46·6339	76	69·4936
2	1·8288	27	24·6885	52	47·5483	77	70·4080
3	2·7432	28	25·6029	53	48·4627	78	71·3224
4	3·6576	29	26·5173	54	49·3771	79	72·2368
5	4·5719	30	27·4317	55	50·2914	80	73·1512
6	5·4863	31	28·3461	56	51·2058	81	74·0656
7	6·4007	32	29·2605	57	52·1202	82	74·9800
8	7·3151	33	30·1749	58	53·0346	83	75·8944
9	8·2295	34	31·0893	59	53·9490	84	76·8088
10	9·1439	35	32·0036	60	54·8634	85	77·7231
11	10·0583	36	32·9180	61	55·7778	86	78·6375
12	10·9727	37	33·8324	62	56·6922	87	79·5519
13	11·8871	38	34·7468	63	57·6066	88	80·4663
14	12·8015	39	35·6612	64	58·5210	89	81·3807
15	13·7158	40	36·5756	65	59·4353	90	82·2951
16	14·6302	41	37·4900	66	60·3497	91	83·2095
17	15·5446	42	38·4044	67	61·2641	92	84·1239
18	16·4590	43	39·3188	68	62·1785	93	85·0383
19	17·3734	44	40·2332	69	63·0929	94	85·9527
20	18·2878	45	41·1475	70	64·0073	95	86·8670
21	19·2022	46	42·0619	71	64·9217	96	87·7814
22	20·1166	47	42·9763	72	65·8361	97	88·6958
23	21·0310	48	43·8907	73	66·7505	98	89·6102
24	21·9454	49	44·8051	74	67·6649	99	90·5246
25	22·8600	50	45·7195	75	68·5792	100	91·4390

TABLE 58.—KILOGRAMMES IN POUNDS.

Kilos.	Pounds.	Kilos.	Pounds.	Kilos.	Pounds.	Kilos.	Pounds.
1	2·2046	13	28·6601	25	55·1155	37	81·5710
2	4·4092	14	30·8647	26	57·3201	38	83·7756
3	6·6139	15	33·0693	27	59·5248	39	85·9802
4	8·8185	16	35·2739	28	61·7294	40	88·1848
5	11·0231	17	37·4786	29	63·9340	41	90·3895
6	13·2277	18	39·6832	30	66·1386	42	92·5941
7	15·4323	19	41·8878	31	68·3433	43	94·7987
8	17·6370	20	44·0924	32	70·5479	44	97·0033
9	19·8416	21	46·2970	33	72·7525	45	99·2079
10	22·0462	22	48·5017	34	74·9571	46	101·4126
11	24·2508	23	50·7063	35	77·1617	47	103·6172
12	26·4555	24	52·9109	36	79·3664	48	105·8218

TABLE 58.—KILOGRAMMES IN POUNDS (*continued*).

Kilos.	Pounds.	Kilos.	Pounds.	Kilos.	Pounds.	Kilos.	Pounds.
49	108·0264	**62**	136·4865	**75**	165·3466	**88**	194·0066
50	110·2310	**63**	138·8911	**76**	167·5512	**89**	196·2113
51	112·4357	**64**	141·0957	**77**	169·7558	**90**	198·4159
52	114·6403	**65**	143·3004	**78**	171·9604	**91**	200·6205
53	116·8449	**66**	145·5050	**79**	174·1651	**92**	202·8251
54	119·0495	**67**	147·7096	**80**	176·3697	**93**	205·0298
55	121·2542	**68**	149·9142	**81**	178·5743	**94**	207·2344
56	123·4588	**69**	152·1188	**82**	180·7789	**95**	209·4390
57	125·6634	**70**	154·3235	**83**	182·9835	**96**	211·6436
58	127·8680	**71**	156·5281	**84**	185·1182	**97**	213·8482
59	130·0726	**72**	158·7327	**85**	187·3928	**98**	216·0529
60	132·2773	**73**	160·9373	**86**	189·5974	**99**	218·2575
61	134·4819	**74**	163·1420	**87**	191·8020	**100**	220·4621

TABLE 59.—POUNDS IN KILOGRAMMES.

Pounds.	Kilogrs.	Pounds.	Kilogrs.	Pounds.	Kilogrs.	Pounds.	Kilogrs.
1	·4536	**26**	11·7934	**51**	23·1332	**76**	34·4731
2	·9072	**27**	12·2470	**52**	23·5868	**77**	34·9267
3	1·3608	**28**	12·7006	**53**	24·0404	**78**	35·3803
4	1·8144	**29**	13·1542	**54**	24·4940	**79**	35·8338
5	2·2680	**30**	13·6078	**55**	24·9476	**80**	36·2874
6	2·7216	**31**	14·0614	**56**	25·4012	**81**	36·7410
7	3·1752	**32**	14·5150	**57**	25·8548	**82**	37·1946
8	3·6287	**33**	14·9686	**58**	26·3084	**83**	37·6482
9	4·0823	**34**	15·4222	**59**	26·7620	**84**	38·1018
10	4·5359	**35**	15·8758	**60**	27·2516	**85**	38·5554
11	4·9895	**36**	16·3293	**61**	27·6692	**86**	39·0090
12	5·4431	**37**	16·7829	**62**	28·1227	**87**	39·4626
13	5·8967	**38**	17·2365	**63**	28·5764	**88**	39·9162
14	6·3503	**39**	17·6901	**64**	29·0300	**89**	40·3700
15	6·8039	**40**	18·1437	**65**	29·4835	**90**	40·8234
16	7·2575	**41**	18·5973	**66**	29·9371	**91**	41·2770
17	7·7111	**42**	19·0509	**67**	30·3907	**92**	41·7306
18	8·1647	**43**	19·5045	**68**	30·8443	**93**	42·1841
19	8·6183	**44**	19·9581	**69**	31·2979	**94**	42·6377
20	9·0719	**45**	20·4117	**70**	31·7515	**95**	43·0913
21	9·5255	**46**	20·8653	**71**	32·2051	**96**	43·5449
22	9·9790	**47**	21·3189	**72**	32·6587	**97**	43·9985
23	10·4326	**48**	21·7725	**73**	33·1123	**98**	44·4521
24	10·8862	**49**	22·2261	**74**	33·5659	**99**	44·9057
25	11·3398	**50**	22·6796	**75**	34·0195	**100**	45·3593

TABLE 60.—SQUARE METRES IN SQUARE FEET AND SQUARE YARDS.

Square Metres.	Square Feet.	Square Yards.	Square Metres	Square Feet.	Square Yards.
1	10·7641	1·1960	**42**	452·0930	50·2320
2	21·5282	2·3920	**43**	462·8572	51·4280
3	32·2924	3·5880	**44**	473·6213	52·6240
4	43·0565	4·7840	**45**	484·3854	53·8200
5	53·8206	5·9800	**46**	495·1495	55·0160
6	64·5847	7·1760	**47**	505·9136	56·2120
7	75·3458	8·3720	**48**	516·6778	57·4080
8	86·1130	9·5680	**49**	527·4419	58·6040
9	96·8771	10·7640	**50**	538·2060	59·8000
10	107·6412	11·9600	**51**	548·9701	60·9960
11	118·4053	13·1560	**52**	559·7342	62·1920
12	129·1694	14·3520	**53**	570·4984	63·3880
13	139·9336	15·5480	**54**	581·2625	64·5840
14	150·6977	16·7440	**55**	592·0266	65·7800
15	161·4618	17·9400	**56**	602·7907	66·9760
16	172·2259	19·1360	**57**	613·5548	68·1720
17	182·9900	20·3320	**58**	624·3190	69·3680
18	193·7542	21·5280	**59**	635·0831	70·5640
19	204·5183	22·7240	**60**	645·8472	71·7600
20	215·2824	23·9200	**61**	656·6113	72·9560
21	226·0465	25·1160	**62**	667·3754	74·1520
22	236·8106	26·3120	**63**	678·1396	75·3480
23	247·5748	27·5080	**64**	688·9037	76·5440
24	258·3389	28·7040	**65**	699·6678	77·7400
25	269·1030	29·9000	**66**	710·4319	78·9360
26	279·8671	31·0960	**67**	721·1960	80·1320
27	290·6312	32·2920	**68**	731·9602	81·3280
28	301·3954	33·4880	**69**	742·7243	82·5240
29	312·1595	34·6840	**70**	753·4884	83·7200
30	322·9236	35·8800	**71**	764·2525	84·9160
31	333·6877	37·0760	**72**	775·0166	86·1120
32	344·4518	38·2720	**73**	785·7808	87·3080
33	355·2160	39·4680	**74**	796·5449	88·5040
34	365·9801	40·6640	**75**	807·3090	89·7000
35	376·7442	41·8600	**76**	818·0731	90·8960
36	387·5083	43·0560	**77**	828·8372	92·0920
37	398·2724	44·2520	**78**	839·6014	93·2880
38	409·6366	45·4480	**79**	850·3655	94·4840
39	419·8007	46·6440	**80**	861·1296	95·6800
40	430·5648	47·8400	**81**	871·8937	96·8760
41	441·3289	49·0360	**82**	882·6578	98·0720

TABLE 60.—SQUARE METRES IN SQUARE FEET AND SQUARE YARDS (*continued*).

Square Metres.	Square Feet.	Square Yards.	Square Metres.	Square Feet.	Square Yards.
83	893·4220	99·2680	**92**	990·2990	110·0320
84	904·1861	100·4640	**93**	1001·0632	111·2280
85	914·9502	101·6600	**94**	1011·8273	112·4240
86	925·7143	102·8560	**95**	1022·5914	113·6200
87	936·4784	104·0520	**96**	1033·3555	114·8160
88	947·2426	105·2480	**97**	1044·1196	116·0120
89	958·0067	106·4440	**98**	1054·8838	117·2080
90	968·7708	107·6400	**99**	1065·6479	118·4040
91	979·5349	108·8360	**100**	1076·4120	119·6000

TABLE 61.—SQUARE FEET IN SQUARE METRES.

Square Feet.	Square Metres.	Square Feet.	Square Metres.	Square Feet.	Square Metres.	Square Feet.	Square Metres.
1	·0929	**26**	2·4154	**51**	4·7380	**76**	7·0605
2	·1858	**27**	2·5083	**52**	4·8309	**77**	7·1534
3	·2787	**28**	2·6012	**53**	4·9238	**78**	7·2463
4	·3716	**29**	2·6941	**54**	5·0167	**79**	7·3392
5	·4645	**30**	2·7870	**55**	5·1096	**80**	7·4321
6	·5574	**31**	2·8799	**56**	5·2025	**81**	7·5250
7	·6503	**32**	2·9728	**57**	5·2954	**82**	7·6179
8	·7432	**33**	3·0657	**58**	5·3883	**83**	7·7108
9	·8361	**34**	3·1586	**59**	5·4812	**84**	7·8037
10	·9290	**35**	3·2515	**60**	5·5741	**85**	7·8966
11	1·0219	**36**	3·3444	**61**	5·6670	**86**	7·9895
12	1·1148	**37**	3·4373	**62**	5·7599	**87**	8·0824
13	1·2077	**38**	3·5302	**63**	5·8528	**88**	8·1753
14	1·3006	**39**	3·6231	**64**	5·9457	**89**	8·2682
15	1·3935	**40**	3·7160	**65**	6·0386	**90**	8·3611
16	1·4864	**41**	3·8089	**66**	6·1315	**91**	8·4540
17	1·5793	**42**	3·9018	**67**	6·2244	**92**	8·5469
18	1·6722	**43**	3·9947	**68**	6·3173	**93**	8·6398
19	1·7651	**44**	4·0876	**69**	6·4102	**94**	8·7327
20	1·8580	**45**	4·1805	**70**	6·5031	**95**	8·8256
21	1·9509	**46**	4·2734	**71**	6·5960	**96**	8·9185
22	2·0438	**47**	4·3663	**72**	6·6889	**97**	9·0114
23	2·1367	**48**	4·4592	**73**	6·7818	**98**	9·1043
24	2·2296	**49**	4·5521	**74**	6·8747	**99**	9·1972
25	2·3225	**50**	4·6450	**75**	6·9676	**100**	9·2901

TABLE 62.—SQUARE YARDS IN SQUARE METRES.

Square Yards.	Square Metres.	Square Yards.	Square Metres.	Square Yards.	Square Metres.	Square Yards.	Square Metres.
1	·8361	26	21·7389	51	42·6417	76	63·5445
2	1·6722	27	22·5750	52	43·4778	77	64·3806
3	2·5083	28	23·4111	53	44·3139	78	65·2167
4	3·3444	29	24·7472	54	45·1500	79	66·0528
5	4·1806	30	25·0834	55	45·9862	80	66·8890
6	5·0167	31	25·9195	56	46·8223	81	67·7251
7	5·8528	32	26·7556	57	47·6584	82	68·5612
8	6·6889	33	27·5917	58	48·4945	83	69·3973
9	7·5250	34	28·4278	59	49·3306	84	70·2334
10	8·3611	35	29·2639	60	50·1667	85	71·0695
11	9·1972	36	30·1000	61	51·0028	86	71·9056
12	10·0333	37	30·9361	62	51·8389	87	72·7417
13	10·8695	38	31·7723	63	52·6751	88	73·5779
14	11·7056	39	32·6084	64	53·5112	89	74·4140
15	12·5417	40	33·4445	65	54·3473	90	75·2501
16	13·3778	41	34·2806	66	55·1834	91	76·0862
17	14·2139	42	35·1167	67	56·0195	92	76·9223
18	15·0500	43	35·9528	68	56·8556	93	77·7584
19	15·8861	44	36·7889	69	57·6917	94	78·5945
20	16·7222	45	37·6250	70	58·5278	95	79·4306
21	17·5584	46	38·4612	71	59·3640	96	80·2668
22	18·3945	47	39·2973	72	60·2001	97	81·1029
23	19·2306	48	40·1334	73	61·0362	98	81·9390
24	20·0667	49	40·9695	74	61·8723	99	82·7751
25	20·9028	50	41·8056	75	62·7085	100	83·6112

TABLE 63.—CUBIC METRES IN CUBIC FEET AND CUBIC YARDS.

Cubic Metres.	Cubic Feet.	Cubic Yards.	Cubic Metres.	Cubic Feet.	Cubic Yards.
1	35·3156	1·3080	10	353·1560	13·0800
2	70·6312	2·6160	11	388·4716	14·3880
3	105·9468	3·9240	12	423·7872	15·6960
4	141·2624	5·2320	13	459·1028	17·0040
5	176·5780	6·5400	14	494·4184	18·3120
6	211·8936	7·8480	15	529·7340	19·6200
7	247·2092	9·1560	16	565·0496	20·9280
8	282·5248	10·4640	17	600·3652	22·2360
9	317·8404	11·7720	18	635·6808	23·5440

TABLE 63.—CUBIC METRES IN CUBIC FEET AND CUBIC YARDS (*continued*).

Cubic Metres.	Cubic Feet.	Cubic Yards.	Cubic Metres.	Cubic Feet.	Cubic Yards.
19	670·9964	24·8520	**60**	2118·9360	78·4800
20	706·3120	26·1600	**61**	2154·2516	79·7880
21	741·6276	27·4680	**62**	2189·5672	81·0960
22	776·9432	28·7760	**63**	2224·8828	82·4040
23	812·2588	30·0840	**64**	2260·1984	83·7120
24	847·5744	31·3920	**65**	2295·5140	85·0200
25	882·8900	32·7000	**66**	2330·8296	86·3280
26	918·2056	34·0080	**67**	2366·1452	87·6360
27	953·5212	35·3160	**68**	2401·4608	88·9440
28	988·8368	36·6240	**69**	2436·7764	90·2520
29	1024·1524	37·9320	**70**	2472·0920	91·5600
30	1059·4680	39·2400	**71**	2507·4076	92·8680
31	1094·7836	40·5480	**72**	2542·7232	94·1760
32	1130·0992	41·8560	**73**	2578·0388	95·4840
33	1165·4148	43·1640	**74**	2613·3544	96·7920
34	1200·7304	44·4720	**75**	2648·6700	98·1000
35	1236·0460	45·7800	**76**	2683·9856	99·4080
36	1271·3616	47·0880	**77**	2719·3012	100·7160
37	1306·6772	48·3960	**78**	2754·6168	102·0240
38	1341·9928	49·7040	**79**	2789·9324	103·3320
39	1377·3084	51·0120	**80**	2825·2480	104·6400
40	1412·6240	52·3200	**81**	2860·5636	105·9480
41	1447·9396	53·6280	**82**	2895·8792	107·2560
42	1483·2552	54·9360	**83**	2931·1948	108·5640
43	1518·5708	56·2440	**84**	2966·5104	109·8720
44	1553·8864	57·5520	**85**	3001·8260	111·1800
45	1589·2020	58·8600	**86**	3037·1416	112·4880
46	1624·5176	60·1680	**87**	3072·4572	113·7960
47	1659·8332	61·4760	**88**	3107·7728	115·1040
48	1695·1488	62·7840	**89**	3143·0884	116·4120
49	1730·4644	64·0920	**90**	3178·4040	117·7200
50	1765·7800	65·4000	**91**	3213·7196	119·0280
51	1801·0956	66·7080	**92**	3249·0352	120·3360
52	1836·4112	68·0160	**93**	3284·3508	121·6440
53	1871·7268	69·3240	**94**	3319·6664	122·9520
54	1907·0424	70·6320	**95**	3354·9820	124·2600
55	1942·3580	71·9400	**96**	3390·2976	125·5680
56	1977·6736	73·2480	**97**	3425·6132	126·8760
57	2012·9892	74·5560	**98**	3460·9288	128·1840
58	2048·3048	75·8640	**99**	3496·2444	129·4920
59	2083·6204	77·1720	**100**	3531·5600	130·8000

TABLE 64.—CUBIC FEET IN CUBIC METRES.

Cubic Feet.	Cubic Metres.	Cubic Feet.	Cubic Metres.	Cubic Feet.	Cubic Metres.	Cubic Feet.	Cubic Metres.
1	·0283	**26**	·7362	**51**	1·4450	**76**	2·1519
2	·0566	**27**	·7645	**52**	1·4724	**77**	2·1803
3	·0849	**28**	·7928	**53**	1·5007	**78**	2·2086
4	·1133	**29**	·8211	**54**	1·5290	**79**	2·2369
5	·1416	**30**	·8494	**55**	1·5573	**80**	2·2652
6	·1699	**31**	·8778	**56**	1·5856	**81**	2·2935
7	·1982	**32**	·9061	**57**	1·6140	**82**	2·3218
8	·2265	**33**	·9344	**58**	1·6423	**83**	2·3501
9	·2548	**34**	·9627	**59**	1·6706	**84**	2·3785
10	·2831	**35**	·9910	**60**	1·6989	**85**	2·4068
11	·3115	**36**	1·0193	**61**	1·7272	**86**	2·4351
12	·3398	**37**	1·0477	**62**	1·7555	**87**	2·4634
13	·3681	**38**	1·0760	**63**	1·7838	**88**	2·4917
14	·3964	**39**	1·1043	**64**	1·8122	**89**	2·5200
15	·4247	**40**	1·1326	**65**	1·8405	**90**	2·5483
16	·4530	**41**	1·1609	**66**	1·8688	**91**	2·5767
17	·4814	**42**	1·1892	**67**	1·8971	**92**	2·6050
18	·5097	**43**	1·2175	**68**	1·9254	**93**	2·6333
19	·5380	**44**	1·2459	**69**	1·9537	**94**	2·6616
20	·5663	**45**	1·2742	**70**	1·9820	**95**	2·6899
21	·5946	**46**	1·3025	**71**	2·0104	**96**	2·7182
22	·6229	**47**	1·3308	**72**	2·0387	**97**	2·7466
23	·6512	**48**	1·3591	**73**	2·0670	**98**	2·7749
24	·6795	**49**	1·3874	**74**	2·0953	**99**	2·8032
25	·7079	**50**	1·41570	**75**	2·1236	**100**	2·8315

TABLE 65.—CUBIC YARDS IN CUBIC METRES.

Cubic Yards.	Cubic Metres.	Cubic Yards.	Cubic Metres.	Cubic Yards.	Cubic Metres.	Cubic Yards.	Cubic Metres.
1	·7645	**11**	8·4096	**21**	16·0548	**31**	23·6999
2	1·5290	**12**	9·1742	**22**	16·8193	**32**	24·4644
3	2·2935	**13**	9·9387	**23**	17·5838	**33**	25·2289
4	3·0581	**14**	10·7032	**24**	18·3483	**34**	25·9934
5	3·8226	**15**	11·4677	**25**	19·1128	**35**	26·7580
6	4·5871	**16**	12·2322	**26**	19·8773	**36**	27·5225
7	5·3516	**17**	12·9967	**27**	20·6419	**37**	28·2870
8	6·1161	**18**	13·7612	**28**	21·4064	**38**	29·0515
9	6·8806	**19**	14·5257	**29**	22·1709	**39**	29·8160
10	7·6451	**20**	15·2903	**30**	22·9354	**40**	30·5805

TABLE 65.—CUBIC YARDS IN CUBIC METRES (*continued*).

Cubic Yards.	Cubic Metres.	Cubic Yards.	Cubic Metres.	Cubic Yards.	Cubic Metres.	Cubic Yards.	Cubic Metres.
41	31·3450	**56**	42·8127	**71**	54·2804	**86**	65·7481
42	32·1095	**57**	43·5772	**72**	55·0449	**87**	66·5126
43	32·8741	**58**	44·3418	**73**	55·8094	**88**	67·2771
44	33·6386	**59**	45·1063	**74**	56·5740	**89**	68·0417
45	34·4031	**60**	45·8708	**75**	57·3385	**90**	68·8062
46	35·1676	**61**	46·6353	**76**	58·1030	**91**	69·5707
47	35·9321	**62**	47·3998	**77**	58·8675	**92**	70·3352
48	36·6966	**63**	48·1643	**78**	59·6320	**93**	71·0997
49	37·4611	**64**	48·9288	**79**	60·3965	**94**	71·8642
50	38·2256	**65**	49·6933	**80**	61·1610	**95**	72·6287
51	38·9902	**66**	50·4579	**81**	61·9256	**96**	73·3932
52	39·7547	**67**	51·2224	**82**	62·6901	**97**	74·1578
53	40·5192	**68**	51·9869	**83**	63·4546	**98**	74·9223
54	41·2837	**69**	52·7514	**84**	64·2191	**99**	75·6868
55	42·0482	**70**	53·5159	**85**	64·9836	**100**	76·4513

TABLE 66.—APPROXIMATE EQUIVALENTS OF FRENCH AND ENGLISH MEASURES.

1 chain (22 yards)	20 metres (exactly 22·1166 metres).
5 furlongs	1 kilometre (exactly 1·0058 kilometres).
1 foot	3 decimetres (exactly 3·048 decimetres). 30 centimetres.
1 metre	3·28 feet. 3 feet 3 inches $\frac{3}{8}$ inch ($\frac{1}{512}$ inch less). 40 inches (1·6 per cent. less).
1 inch	25 millimetres (exactly 25·4).
1 yard	$\frac{11}{12}$ metre.
11 metres	12 yards.
To convert metres into yards	Add $\frac{1}{11}$th.
1 kilometre	$\frac{5}{8}$ mile.
1 mile	1·6 or $1\frac{3}{5}$ kilometres.
1 square inch	6·5 square centimetres.
1 square metre	$10\frac{3}{4}$ square feet. $1\frac{1}{5}$ square yards.
1 square yard	$\frac{5}{6}$ square metre.
1 acre	4000 square metres (1·2 per cent. more).
1 square mile	260 hectares (0·4 per cent. less).

1 cubic yard . . .	¾ cubic metre (2 per cent. more).
1 cubic metre . .	1⅓ cubic yard (1⅔ per cent. less).
1 cubic metre . . .	35⅓ cubic feet (·05 per cent. less).
1 litre	1¾ pints fully.
1 gallon	4½ litres fully.
1 cubic foot . . .	28·3 litres.
1 cubic metre of water .	1 ton nearly.
1 gramme . . .	15½ grains nearly.
1 kilogramme . . .	2·2 pounds fully.
1000 kilogrammes 1 metric ton .	1 ton nearly.
1 hundredweight . . .	51 kilogrammes nearly.

TABLE 67.—FRENCH AND ENGLISH COMPOUND EQUIVALENTS.

1 kilogramme per lineal metre	·672 pound per lineal foot. 2·016 pounds per yard.
1000 kilogrammes (1 tonne) per metre	·300 ton per foot.
1 kilogramme per kilometre .	3·548 pounds per mile.
1000 kilogrammes (1 tonne) per kilometre . . .	1·584 tons per mile.
1 kilogramme per square millimetre	1422·32 pounds per square inch. ·635 ton per square inch.
1 kilogramme per square centimetre	14·2232 pounds per square inch.
1 kilogramme per square decimetre	20·4776 pounds per square foot.
1 kilogramme per square metre	1·8430 pounds per square yard.
1000 kilogrammes (1 tonne) per square metre . .	·8229 ton per square yard.
1 kilogramme per tonne . .	2·240 pounds per ton.
1 kilogramme per tonne per kilometre	3·6042 pounds per ton per mile.
1 litre of water at 4° C. per tonne per kilometre .	3·6042 pounds per ton per mile. ·3599 gallon at 62° F. per ton per mile.
1 gramme per square millimetre	1·422 pounds per square inch.
1 gramme per square centimetre	·01422 pound per square inch.
1 kilogramme per cubic metre	1·686 pounds per cubic yard. ·0624 pound per cubic foot.
1000 kilogrammes (1 tonne) per cubic metre . . .	·984 ton per cubic metre. ·752 ton per cubic yard.

1 cubic metre per kilogramme	16·019 cubic feet per pound.
1 cubic metre per tonne . .	1·329 cubic yards per ton. 35·882 cubic feet per ton.
1 cubic metre per kilometre .	2·105 cubic yards per mile.
1 gramme per litre . .	73·09 grains per gallon.
1 kilogramme per litre . .	10·4382 pounds per gallon.
1 cubic metre per lineal metre	1·196 cubic yards per lineal yard.
1 cubic metre per square metre	3·281 cubic feet per square foot.
1 litre per square metre . .	·0204 gallon per square foot.
1 cubic metre per hectare . .	·405 cubic metre per acre. ·529 cubic yard per acre. 89·065 gallons per acre.
1 kilogrammetre . . .	7·233 foot-pounds.
1 tonne-metre	3 foot-tons.
1 cheval vapeur, or cheval (75k × m per second) . .	·9863 horse-power.
1 kilogramme per cheval .	2·235 pounds per horse-power.
1 square metre per cheval .	10·913 square feet per horse-power.
1 cubic metre per cheval .	35·806 cubic feet per horse-power.
1 calorie or French unit of heat	3·968 English heat-units.
French mechanical equivalent of heat (425 kilogrammetres)	3074 foot-pounds per unit.
1 calorie per square metre .	·369 heat-unit per square foot.
1 calorie per kilogramme .	1·800 heat-units per pound.
1 franc per kilogramme . .	·360 shillings per pound. £40·32 per ton.
1 franc per quintal . .	·403 shillings per cwt.
1 franc per tonne . . .	·484 penny per cwt. ·806 shilling per ton.
1 franc per metre . . .	·726 shilling per yard. 8·709 pence per yard.
1 franc per kilometre . .	£·06386 per mile. 15·326 pence per mile.
1 franc per square metre .	7·963 pence per square yard. ·6636 shilling per square yard.
1 franc per cubic metre .	7·281 pence per cubic yard.
1 franc per litre . . .	3·606 shillings per gallon.
1 franc per hectolitre . .	1·893 shillings per hogshead.

TABLE 68.—ENGLISH AND FRENCH COMPOUND EQUIVALENTS.

1 pound per lineal foot	1·488 kilogrammes per lineal metre.
1 pound per yard	·496 kilogramme per metre.
1 ton per foot	3333·333 kilogrammes (3⅓ tons) per metre.
1 ton per yard	1111·111 kilogrammes (1⅑ tons) per metre.
1 pound per mile	·2818 kilogrammes per kilometre.
1 ton per mile	·6313 tonne per kilometre.
1 pound per ton	·4464 kilogramme per tonne.
1 pound per ton per mile	·2774 kilogramme per tonne per kilometre.
1 pound per square inch	·0703077 kilogramme per square centimetre. ·7031 gramme per square millimetre. 5·170 centimetres of mercury at 0° C.
1 atmosphere (14·7 pounds per square inch)	1·0335 kilogrammes per square centimetre.
1000 pounds per square inch	·703077 kilogramme per square millimetre.
2000 pounds per square inch	1·406154 kilogrammes per square millimetre.
1 ton per square inch	1·575 kilogrammes per square millimetre.
1 pound per square foot	4·883 kilogrammes per square metre.
1000 pounds per square foot	4882·517 kilogrammes per square metre.
1 ton per square foot	10·936 tonnes per square metre.
1000 pounds per square yard	542·500 kilogrammes per square metre.
1 ton per square yard	1·215 tonnes per square metre.
1 pound per cubic yard	·5933 kilogramme per cubic metre.
1 pound per cubic foot	16·020 kilogrammes per cubic metre.
1 ton per cubic yard	1·329 tonnes per cubic metre.
1 cubic yard per pound	1·6855 cubic metres per kilogramme.
1 cubic yard per ton	·7525 cubic metre per tonne.
1 cubic yard per mile	·4750 cubic metre per kilometre.

1 grain per gallon . . .	·01426 gramme per litre.
1 pound per gallon . . .	·09983 kilogramme per litre.
1 cubic yard per lineal yard .	·836 cubic metre per lineal metre.
1 cubic foot per square foot .	3·048 cubic metres per square metre.
1 gallon per square foot .	48·905 litres per square metre.
1 cubic metre per acre . .	2·471 cubic metres per hectare.
1 cubic yard per acre . .	1·902 cubic metres per hectare.
1000 gallons per acre . .	11·226 cubic metres per hectare.
1 foot-pound	·1382 kilogrammetre.
1 foot-ton	·3333 tonne-metre.
1 horse-power	1·0139 cheval.
1 pound per horse-power .	·447 kilogramme per cheval.
1 square foot per horse-power	·0196 square metre per cheval.
1 cubic foot per horse-power.	·0279 cubic metre per cheval.
1 English unit of heat, or heat-unit	·252 calorie.
English mechanical equivalent to one heat-unit (772 foot-pounds)	10·67 kilogrammetres.
1 English heat-unit per square foot	2·713 calories per square metre.
1 English heat-unit per pound	$\frac{5}{9}$ calorie per kilogramme.
1 penny per pound . . .	·231 franc per kilogramme.
1 shilling per pound . .	2·772 franc per kilogramme.
1 shilling per cent. or . . £1 per ton	24·802 francs per tonne. 2·48 francs per quintal.
1 shilling per yard . .	1·378 francs per metre.
1 penny per mile . . .	·0652 franc per kilometre.
£1 per mile	15·660 francs per kilometre.
1 shilling per square yard .	1·510 francs per square metre.
£1 per square yard . . .	30·194 francs per square metre.
1 penny per cubic foot . .	3·708 francs per cubic metre.
1 penny per cubic yard . .	·137 franc per cubic metre.
1 shilling per cubic yard .	1·648 francs per cubic metre.
£1 per cubic yard . . .	32·962 francs per cubic metre.
1 shilling per hogshead. .	·528 franc per hectolitre.
1 penny per gallon . . .	·0231 franc per litre.

EUROPE.

Austria-Hungary.

Length. 1 Fuss = 1·0371 feet ; 2 Fuss = 1 Elle = 2·0742 feet ; 6 Fuss = 1 Klafter = 6·2226 feet ; 4000 Klafter = 1 Meile = 4·714 miles.

Surface. 1 square Klafter = 38·7225 square feet = 4·3025 square yards; 1600 square Klafter = 1 Joch = 1·4223 acres.

Volume. 1 cubic Klafter = 240·94 cubic feet = 8·924 cubic yards.

Capacity, dry. 1 Achtel = 1·6920 gallons; 2 Achtel = 1 Viertel = 3·3840 gallons = ·4230 bushel; 4 Viertel = 1 Metze = 1·6918 bushels.

Capacity, liquid. 1 Kanne = 1·2457 pints; 2 Kannen = 1 Mass = 1·2457 quarts; 10 Mass = 1 Viertel = 3·1143 gallons; 4 Viertel = 1 Eimer = 12·4572 gallons.

Weight. 1 Pfund = 1·2347 pounds; 100 Pfund = 1 Centner = 123·47 pounds = 1·1024 hundredweights.

The French metric system of weights and measures is legal in Austria-Hungary.

Belgium.

The French metric system is in force in Belgium. The name *aune* is substituted for metre, *litron* for litre, *livre* for kilogramme.

Denmark.

Length. 1 Fod = 1·0297 feet; 6 Fod = 1 Favn = 6·1783 feet; 1 Mil = 4·68055 miles.

Surface. 1 square Fod = 1·0603 square feet; 144 square Fod = 1 square Rode = 16·966 square yards.

Volume. 1 cubic Fod = 1·0918 cubic feet. The Favn of firewood = 6 Fod × 6 Fod × 2 Fod = 72 cubic Fod = 78·60 cubic feet.

Capacity, liquid. 38 Potter = 1 Anker = 8·0709 gallons; 136 Potter = 1 Tönde = 28·885 gallons.

Capacity, dry. 1 Tönde or barrel of grain or salt = 3·8231 bushels; barrel of coal = 4·7 bushels.

Weight. 100 Kvinten = 1 Pund = 1·1023 pounds; 100 Pund = 1 Centner = 110·23 pounds; 40 Centner = 1 Last = 1·9684 tons; 1 Skip-last = 2·5590 tons.

Germany.

The French metrical system of weights and measures came into force in Germany, on January 1, 1872.

Length. The metre is known as the *Stab;* the centimetre, the *Neu-Zoll;* the kilometre is the same; 7 kilometres = 1 mile = 4·35 English miles.

Surface. The square metre is the *Quadrat-stab;* the are is the *Ar;* the hectare is the *Hectar.* The square kilometre is the *Quadrat* = 247·11 acres.

Volume. 2 Schoppens = 1 Kanne = 1 litre; 50 kannes = 1 scheffel = 50 litres = 1·376 bushels; 2 scheffels = 1 Fass (cask) = 1 hectolitre = 22·01 gallons.

Weight. The milligramme, centigramme, and decigramme are respectively the *Milligram*, *Centigramm*, and *Dezigramm*. 100 dezigramms = 1 Neu-loth = 10 grammes = ·35273 ounce; 50 neu-loths = 1 Pfund = ½ kilogramme = 1·1023 pounds; 100 pfunds = 1 Centner = 50 kilogrammes = 110·23 pounds; 20 centners = 1 tonne = 2204·6 pounds or ·9842 ton.

Greece.

The French metric system is employed in Greece. The metre is the *pecheus*, the kilometre the *stadion*, the are the *stremma;* the litre the *litra*, the gramme the *drachmé*. 1½ kilogrammes = 1 Mnâ; 1½ quintals = 1 tolanton; 1½ tonneaux = 1 Tono = 29·526 hundredwt.

Italy.

The French metric system is in force. The metre is known as the *metro;* the kilometre. *chilometro;* the are, *aro;* the hectare, *ettaro;* the litre, *litro;* the gramme, *gramo;* the tonne, *tonnellata*.

Netherlands.

The French metric system is in force in the Netherlands. The French nomenclature is followed, with but trifling variations.

Portugal.

The French metric system is the legal standard. The old measures principally still in use are: the libra = 1·012 pounds; the almude of Lisbon = 3·7 gallons; the almude of Oporto = 5·6 gallons; the alquiere = ·36 bushel; the moio = 2·78 quarters.

Roumania.

The French metric system is in force in Roumania. Turkish weights and measures are largely in use by the people.

Russia.

Length. 1 Vershok = 1·75 inches; 16 Vershoks = 1 Arschine = 28 inches; 3 Arschines = 1 Sajene = 7 feet; 500 Sajenes = 1 Verst = 3,500 feet or ·6629 mile. The English foot decimally divided is the ordinary standard of length. The Rhein Fuss (= 1·03 English feet) is used in calculating export duties on timber.

Surface. 1 square Arschine = 5·444 square feet; 9 square arschines = 1 square sajeen = 49 square feet; 2,400 square sajeens = 1 Desatine = 2·70 acres. For earthworks, masonry, &c., the sajene is divided into tenths (dessiatka), hundredths (Sotka), and thousandths (tisiatchka). These are squared and cubed, for superficial and cubic measurements.

Capacity, liquid. 1 Tscharkey = ·2164 pint; 10 tscharkeys = 1 Krushka = 1·0820 quarts; 100 tscharkeys = 1 Vedro = 2·7049 gallons; 3 vedros = 1 anker = 8·1147 gallons; 40 Vedros = 1 Sarokowaja Boshka = 108·196 gallons.

Capacity, dry. (Grain.) 1 Tschetwert = 5·7704 bushels (usually reckoned at 5¾ bushels); 16 Tschetwerts = 1 Last = 11·5408 quarters. 100 Tschetwerts are usually reckoned equal to 72 quarters; they are exactly 72·1308 quarters.

Weight. 12 lanas = 32 lottis = 96 Zolotnicks = 1 Funt or pound = ·90285 English pound = 14·446 ounces; 40 pounds = 1 Pood = 36·114 English pounds; 62·0257 Poods = 1 English ton; 1 ship-last = 1·89 English tons.

Servia.

The French metric system has been in use in Servia since 1883. The old Turkish and Austrian weights and measures still linger in outlying districts.

Spain.

The French metric system has been established in Spain since 1859. The metre is the *metro;* the litre, the *litro;* the gramme the *gramo;* the are, the *area.* The old system continues largely in use.

Length. 12 lineas = 1 pulgada = ·927 inch; 12 pulgadas = 1 Pies de Burgos = ·9273 foot; 3 Pies = 1 Vara = 2·782 feet; 5,000 Varas = 1 Legua (Castilian) = 2·6345 miles; 8,000 Varas = 1 Legua (Spanish) = 4·2151 miles.

Surface. 1 square Vara = ·860 square yard; 16 square Varas = 1 square Estadal = 13·759 square yards; 576 square Estadals = 1 Fanegada = 1·6374 acres.

Capacity, liquid. 4 Cuartillas = 1 Arroba Mayor (for wine) = 3·552 gallons; 1 Arroba Menor (for oil), 2·7652 gallons.

Capacity, dry. 12 Amuerzas = 1 Fanega = 1·5077 bushels.

Weight. 8 Octavos = 1 Onza = 1·0144 ounces; 16 Onzas = 1 Libra = 1·0144 pounds; 100 Libras = 1 Quintal = 101·442 pounds; 10 Quintals = 1 Tonelada = 1014·42 pounds.

Sweden.

The French metric system became obligatory in Sweden in 1889. The following are measures according to the system formerly in use.

Length. 10 Tumer = 1 Fot = 11·6892 inches; 10 Fot = 1 Stang = 9·7411 feet; 10 Stanger = 1 Ref = 32·4703 yards; 360 Ref = 1 Meile = 6·6417 miles.

Surface. 100 square Tumer = 1 square Fot = ·9489 square foot; 1 square Ref = ·2178 acre; 5·6 square Ref = 1 Tunnland = 1·2198 acres.

Switzerland.

The French metric system has been generally adopted in Switzerland, with some changes of names, and of subdivisions.

Length. 10 Zoll = 1 Fuss (3 decimetres) = 11·811 inches; 6 Fuss = 1 Klafter = 5·9056 feet; 10 Fuss = 1 Ruthe = 9·8427 feet; 1600 Ruthen = 1 Lien = 2·9826 miles.

Surface. 100 square Fuss = 1 square Ruthe = 10·7643 square yards; 400 square Ruthen = 1 Juchart = ·8694 acre; 6400 Jucharten = 1 square Stunde = 5693·52 acres.

Volume. 1000 cubic Zoll = 1 cubic Fuss = ·9535 cubic foot; 1000 cubic Fuss = 1 cubic Ruthe = 35·3166 cubic yards.

Weight. 16 Unzen = 1 Pfund ($\frac{1}{2}$ kilogramme) = 1·1023 pounds; 100 Pfund = 1 Centner = 110·233 pounds = ·9842 hundredweight. The Pfund is legally divided into 500 grammes; but the people generally prefer the divisions into halves, quarters, and eighths.

Turkey.

Length. 1 pike, or drâ, or Andazé (cloth measure) = 27 inches, divided in 24 Kerâts. The Archin (land measure) = 30 inches; 1 Forsang = 3·116 miles divided into 3 Berri; Surveyor's Pik, or the Halebi = 27·9 inches; $5\frac{1}{2}$ Halebis = 1 reed.

Surface. The squares of the Kerât, the Pike, and the Reed. The Feddan is an area of land equal to as much as a yoke of oxen can plough in a day.

Capacity, dry. 900 Dirhems = 1 Rottol = 1·411 quarts; 22 Rottols = 1 Kileh = 7·762 gallons, or ·97 bushels; the chief measure for grain, 100 Kilehs = 12·128 imperial quarters.

Capacity, liquid. 1 Almud = 1·152 gallons; 1 Rottol = 2·5134 pints; 100 Rottols = 1 Cantar = 31·417 gallons.

Weight. The Oke = 2·8342 pounds; 100 Rottolos = 1 Cantar = 124·704 pounds.

Malta.

Length. $3\frac{1}{2}$ palmi = 1 yard; 1 Canna = $2\frac{2}{7}$ yards.

Surface. 1 Salma = 4·964 acres. Approximately, 543 square palmi = 400 square feet; 16 Salmi = 71 acres.

Volume. 1 cubic Tratto = 8 cubic feet; 1 cubic Canna = 343 cubic feet.

Weight. 15 Oncie = 14 ounces; 1 Rotolo = $1\frac{3}{4}$ pounds; 64 Rotoli = 1 hundredwt.; 1 Cantaro = 175 pounds; 1 Quintal = 199 pounds; 64 Cantari = 5 tons.

The weights and measures of Turkey, England, and France, are all in use. The principal units are:—

1 Cantaro = 44 oche = 121·0 pounds (English).
1 Oca = 400 dramme = 2·75 pounds.
1 Dramma = 48·15 grains.
1 Picco = 2·296 feet.
1 Scala = 1914·4 square yards.

Candia.

The Pic = 25·11 inches; the Carga (corn) = 4·19 bushels; the Rotolo = 1·165 pounds; 100 Rotolos = 1 Cantaro = 116·5 pounds; the Okka = 2·65 pounds.

ASIA.

Burmah.

The British yard, foot, and inch are in use in Burmah; also the British measures of capacity.

The toung or cubit of 3 maik or span = 19½ inches; 4 toung = 1 lan (fathom); 7 toung = 1 ta; 1000 ta = 1 taing, nearly two English miles.

Measures of capacity depend upon the teng or basket, the value of which varies for different localities: holding from 23 pounds to 50 pounds of rice. An endeavour has been made to introduce a standard basket, containing 2218·19 cubic inches, not as yet successfully.

1 Kyat = 252 grains; 100 Kyats = 1 Piet-tha = 3·652 pounds avoirdupois.

Ceylon.

The weights and measures of Ceylon are the same as those of the United Kingdom. There are also the Seer = 1·86 pints; 10 parrahs = 1 Amomam = 5·6 bushels.

China.

The Chih of 14·10 English inches is the legal standard in the tariff settled by treaty between Great Britain and China. It is the only authorised measure of length at all the ports of trade. The Fĕn = ·141 inch; the Tsun = 1·41 inches; 10 Chih = 1 Cháng = 11·75 feet; 10 Cháng = 1 Yin = 39·17 yards. At Canton there are four different values of the chih; at Pekin, there are thirteen different chihs.

Surface. 25 square Chih = 1 Kung = 3·36 square yards; 240 Kung = 1 Mou = 806¾ square yards; 100 Mou = 1 King = 16⅔ acres. The Mou is the chief land measure.

Capacity. The Tou = 2½ gallons.

Weight. The Tael = $1\frac{1}{3}$ ounces ; the Katty = $1\frac{1}{3}$ pounds ; the Picul = $133\frac{1}{3}$ pounds.

Cochin China.

The Thuoc, or Cubit, 19·2 inches, is the principal unit of length ; but it varies for different places. The Li is 486 yards ; 10 Li = 1 league = 2·761 miles. 9 square Ngu = 1 square Saö = 64 square yards ; 100 square Saö = 1 square Maö = 1·32 acres. 1 Ai = ·0000006 grain ; 1 Nen = ·8594 pound ; 1 Quan = $687\frac{1}{2}$ pounds ; 1 Hao (grain) = $6\frac{2}{5}$ gallons.

Dutch East Indies—Java.

The legal weights and measures of Dutch India are those of the Netherlands. In Java, other measures are in common use. The Duim = 1·3 inches ; the Ell = 27·08 inches. The Djong of 4 Bahu = 7·015 acres. Measures of capacity are taken by definite weight : 1 Sack = 61·034 pounds : 2 Sacks = 1 Pecul = 122·068 pounds. For liquids, the Kan = ·328 gallon ; the Leager = 127·34 gallons. For weights, the Tael = 1·36 ounces; the Pecul = 135·63 pounds.

Hong Kong.

The British weights and measures are in general use in Hong Hong. There are also the Tael = $1\frac{1}{3}$ ounces ; the Picul = 133 pounds ; the Catty = $1\frac{3}{4}$ pounds ; the Chek = $14\frac{5}{8}$ inches ; the Cheung = $12\frac{3}{16}$ feet.

India—Bengal.

Length. 1 Jow, or Jaub = $\frac{1}{4}$ inch ; 1 Guz = 1 yard ; 1 Coss = 2000 yards, or 1·1364 miles. But the Coss varies from 1 mile to 2 miles in different districts. In the Punjab it is generally 2 miles.

Surface. 4 square Hât'hs = 1 Cowrie = 1 square yard ; 1 Beegah = 1600 square yards, or ·3306 acre. For Government surveys, the following table is used :—

	1 Guz . . .	33 lineal inches.
3 Guz . . .	1 Baus, or Rod . .	$8\frac{1}{4}$ lineal feet.
9 Square Guz . .	1 Square Baus . .	$68\frac{1}{16}$ square feet.
400 Square Baus .	1 Beegah . . .	3025 square yards. ·625 acre.

Capacity. The Seer is taken at 68 cubic inches, or 1·962 pints. But it varies. 5 Seer = 1 Palli ; 40 Seer = 1 Maund = 9·81 gallons. The Sooli = 3·065 bushels.

Weight. The Tola = 180 grains, the weight of a rupee, is the unit of weight ; 5 Tolas = 1 Chittâk ; 80 Tolas = 1 Seer = 2·057 pounds ; 40 Seers = 1 Maund = 82·286 pounds.

India—Bombay.

The Tussoo = 1⅛ inches; 16 Tussoos = 1 Hat'h = 18 inches; 24 Tussoos = 1 Guz = 27 inches. The Builder's Tussoo = 2·3625 inches in Bombay; and 1 inch in Surat.

Surface. The Kutty = 9·8175 square yards; 20 Kutty = 1 Pund = 196·35 square yards; 20 Pund = 1 Beegah = ·8114 acre. In the Revenue Field Survey the English acre is used.

Capacity. The Seer = ·56 pint; 4 Seers = 1 Pylee = 2·2401 pints; 16 Pylees = 1 Parah = 4·4802 gallons; 8 Parahs = 1 Candy = 35·8415 gallons; 25 Parahs = 112·0045 gallons. In timber measurement in Bombay Dockyards, a Covit or Candy = 12·704 cubic feet.

Weight. 1 Seer = 11·2 ounces, 1 Maund = 28 pounds: 1 Candy = 5 cwt.

According to an Act passed in 1871, the primary standard of weight is a *Ser*, equal in weight to one kilogramme = 2·205 pounds avoirdupois. For capacity, the litre is the Standard. The divisions to be decimal.

India—Madras.

The British foot and yard are in use. The Guz = 33 inches; the Baum or Fathom is about 6½ feet. The Nalli-Valli is a little less than 1½ miles; 7 Nalli-Valli = 1 Kâdam, or about 10 miles.

1 Span = 8 inches; 1 Cubit = 18 inches: 8000 Cubits = 1 Cos = 2·27 miles.

Surface. 1 Coolie = 64 square yards; 100 Coolies = 1 Cawnie = 1·3223 acres.

Capacity. 8 Ollucks = 1 Puddee = 1·442 quarts; 8 Puddees = 1 Mercâl = 2·885 gallons; 5 Mercâls = 1 Parah = 14·426 gallons; 80 Parahs = 1 Garee = 18·033 quarters. These measures of capacity, though legal, are not commonly used. The "Customary" Puddee, in general use, has, when slightly heaped, a capacity of 1·504 quarts. The Seer measure is the most common, measuring from 66½ to 67 cubic inches.

Weight. The Tola = 180 grains; 3 Tolas = 1 Pollum = 1·234 ounces; 8 Pollums = 1 Seer = 9·874 ounces; 5 Seers = 1 Viss = 3·086 pounds; 8 Viss = 1 Maund = 24·686 pounds; 20 Maunds = 1 Candy = 4·480 hundredwts. The Vis is usually reckoned as 3⅛ pounds; the Maund as 25 pounds; the Candy as 500 pounds.

Japan.

Length. The Sun = 1·20 inches: 10 Sun = 1 Shiaku = 1 foot nearly; 10 Shiaku = 1 Jô = 9 feet 11¼ inches: 60 Ken = 1 Chô = 119·4 yards; 36 Chô = 1 Ri = 2·442 miles. Cloth is measured by the Shiaku of 15 inches, divided decimally.

Surface. 30 Tsubo = 1 Se = 118·615 square yards; 100 Se = 1 Chō = 2·451 acres.

Capacity. 10 Gō = 1 Shō = ·3973 gallon; 10 Shō = 1 To = 3·970 gallons; 10 To = 1 Koku = 39·703 gallons.

Weight. 10 Fun = 1 Momme = 57·97 grains; 100 Momme = 1 Hiyaku-me = ·828 pound; 1000 Momme = 1 K̂wam-me = 8·282 pounds; 160 Momme = 1 Kiu = 1⅓ pounds; 100 Kiu = 1 Hiyak-Kin = 132½ pounds.

Java. (*See* Dutch East Indies.)

Persia.

The unit of length is the Zer, of various lengths; the most common length is 40·95 inches. 16 Gerehs = 1 Zer. A Farsakh varies from 3·87 miles to 4½ miles in length.

Surface. The measure of surface is the Jerib = from 1000 to 1066 square Zer of 40·95 inches = from 1294 to 1379 square yards.

Capacity. (Dry Goods.) 1 Sextario = ·07236 gallon; 1 Artata = 1·809 bushels. Liquids are sold by weight.

Weight. The unit of weight is the Miskâl = 71 grains; 100 Miskâls = 1 Rotel = 1·014 pounds. 640 Miskâls = 1 Batman (of Tabreez) = 6·49 pounds; 100 Batman (of Tabreez) = 1 Karwâr = 649·142 pounds.

The Batman or Mau is the weight by which most articles are sold. It has very various values in different districts. Corn, straw, coal, &c., are sold by the Karwâr.

Siam.

1 Niu = ·9875 inch; 1 Sen = 131 feet 8 inches; 1 Yot = 9 miles, 1715 yards, 1 foot, 8 inches. 1 Chang = 2⅔ pounds; 50 Chang = 133⅓ pounds.

Straits Settlements.

The unit measure of length is the yard; land is measured by the acre.

The Chupak or quart, of 4 paus = 8 imperial gills; 4 quarts = 1 gantang or gallon = 32 gills.

16 Tahil = 1 Kati = 1⅓ pound; 100 Kati = 1 Picul = 133⅓ pounds; 40 Picul = 1 Koyan = 5333⅓ pounds.

Australasia.

In Fiji, New South Wales, New Zealand, Queensland, South Australia, Tasmania, Victoria, Western Australia, the legal weights and measures are those of the United Kingdom. But the old British measures of capacity are still in use.

In land measurement, a "section" is an area equal to 80 acres.

AFRICA.

Algeria.

The French metrical system only is in use.

Arabia.

The Egyptian weights and measures are used in Arabia.

Cape Colony.

The British system of weights and measures is in use; excepting for land measure, for which the unit is the old Amsterdam Morgen, equal to 2·11654 acres; but it is usually reckoned as 2 acres.

1 Cape foot is equal to 1·033 British foot.

Egypt.

The French metric system was legally established in Egypt in 1876.

Length. In the old system in general use the Pik is the unit of length. The Pik or cubit of the Nile = 20·65 inches; the indigenous Pik = 22·37 inches; the Pik of merchandise = 25·51 inches; the Pik of construction = 29·53 inches; 4·73 Piks of construction = 1 Kassaba, in surveying = 11·65 feet.

Surface. 1 square Pik = 6·055 square feet; 22·41 square Piks = 1 square Kassaba = 15·07 square yards; 333·33 square Kassaba = 1 Feddan = ·9342 acre.

Capacity. 1 Kelah = 3·367 gallons; 2 Kelahs = 1 Webek = 6·734 gallons; 6 Webeks = 1 Ardeb = 40·404 gallons = 6·48 cubic feet. The Guirbah of water is $\frac{1}{15}$ cubic metre = 2·354 cubic feet.

Weight. 16 Kerats = 1 Dirhem = 1·792 drachms; 12 Okiehs or 144 Dirhems = 1 Rottol = ·9821 pound; 100 Rottols = 1 Kantar = 98·207 pounds. 1 Oke = 2·728 pounds.

Liberia.

The weights and measures of Liberia are mostly British.

Mauritius.

The metric system, decreed by the Government of India in 1871, came into force in Mauritius in 1878.

Morocco.

Length. 8 Tomins = 1 Drah = 22·482 inches.

Capacity. 4 Muhds = 1 Saâ = 12·3254 gallons.

Weight. 20 Uckieh = 1 Rotal or Artal = 1·12 pounds; 100 Rotals = 1 Kintar = 112 pounds; for imported articles. There is also the Kintar of 168 pounds (100 Rotals) for internal produce.

Oil is sold by the Kula; the Tangier Kula weighs 28 Rotals = 47 pounds English = 5·29 gallons.

South African Republic.

The weights and measures are the same as those of Cape Colony.

Tunis.

Length. The Dhraâ or Pike is the unit of length. The Arabian Dhraâ, for cotton goods, is 19·224 inches long; the Turkish Dhraâ, for lace and silk; the Dhraâ Endaseh for cloth, 26·4888 inches. The Mil Sahári = ·9149 mile.

Capacity. The Kaffis = 16 Huebas, each of 12 Sahs = 16 bushels.

Weight. 100 Rottolos = 1 Cantar = 109·15 pounds.

AMERICA.

Argentine Republic.

The French metric system was, in 1887, legally and compulsorily established. The old weights and measures comprised the Quintal of 101·40 pounds; the Arroba, 25·35 pounds; the Fanega, 1½ bushels.

Bolivia.

The Vara = ·927 yard; the square Vara = ·859 square yard.

The gallon = ·74 imperial gallon; the Arroba, of 25 pounds, = 25·36 pounds avoirdupois; the Arroba for wines and spirits = 6·70 imperial gallons.

The ounce = 1·014 ounce avoirdupois; 16 ounces = 1 Libra = 1·014 pound; 100 Libras = 1 Quintal = 101·44 pounds.

Brazil.

The French metric system is legally established. The old weights and measures are still partly in use.

Length. The Pollegada = 1·0936 inches; the Pé = 13·1236 inches, or ⅓ metre; the Vara = 1·215 yards; the Milha = 1·2965 miles; 3 Milhas = 1 Legoa = 3·8895 miles; 5 Varas are reckoned equal to 6 yards.

Surface. 64 square Polegadas=1 square Palmo=·5315 square foot; 25 square Palmos=1 square Vara; 4 square Varas=1 square Braça=5·9063 square yards; 4840 square Varas=1 Geira=1·4766 acres.

Weight. The Arratel=1·0119 pounds; 32 Arratels=1 Arroba=32·38 pounds; 4 Arrobas=1 Quintal=129·518 pounds; 13½ Quintals=1 Tonclada=15·6116 hundredwts. Ship's freight is reckoned by the English ton taken as equal to 70 Arrobas.

Canada.

The legal weights and measures are the Imperial yard, the Imperial pound avoirdupois, the Imperial gallon, and the Imperial bushel. The Imperial system is practised, with the exception that the hundredweight=100 pounds, and the ton=2000 pounds. The French metric system is permissive, concurrently with the Standard System.

For sale and delivery of the undermentioned articles, the bushel is to be determined by weighing, unless a bushel by measure be specially agreed upon. The weights equivalent to a bushel are added:—

	lbs.		lbs.
Wheat	60	Potatoes	60
Indian corn	56	Turnips	
Rye	56	Carrots	
Peas	60	Parsnips	60
Barley	48	Beets	
Malt	36	Onions	
Oats	34	Bituminous coal	70
Beans	60	Clover seed	60
Flax seed	50	Timothy	48
Hemp	44	Buck wheat	48
Blue grass seed	14		
Castor beans	40		

Chili.

The French metric system has been legally established in Chili; but the ancient weights and measures are still in use. These are the same as those of Bolivia.

Colombia.

The French metric system is legally established in Colombia. In Custom House business, the kilogramme is the standard of weight. The old weights and measures continue in use in ordinary commerce. The Arroba, of 25 Spanish pounds or 12½ kilogrammes; the Quintal, of 100 Spanish pounds, or 50 kilogrammes; and the Carga, of 250 Spanish pounds, or 125 kilogrammes, are generally used. The libra, or pound, is equal to 1·102 pounds avoirdupois. The yard is the usual measure of length. The Colombian Vara, 80 centimetres, is also used. In liquid measure, the French litre is the legal standard.

Costa Rica.

The French metric system is in use, and its legal establishment is contemplated. The old weights and measures of Spain are in general use.

Cuba.

The old weights and measures of Spain are in general use. In engineering and carpentry, English and French measures also are in use. The French metric system is legalised, and is used in the Customs departments.

Ecuador.

The French metric system is the legal standard of this republic.

Guatemala.

The old weights and measures of Spain are in general use in Guatemala.

Haiti.

The French metric weights and measures are in use in Haiti.

Honduras.

The old weights and measures of Spain are in general use in Honduras.

British Honduras.

The British weights and measures are in use in British Honduras.

Mexico.

The weights and measures of the French metric system are legally established in Mexico. But the old Spanish measures are still in use.

Nicaragua.

The system of weights and measures in Nicaragua is that of the old weights and measures of Spain.

Paraguay.

The old weights and measures of Spain are in general use in Paraguay.

Peru.

The old weights and measures are the same as those of Bolivia and Chili. The French metric system was established in 1860, but is not yet in common use, except for the Customs tariff.

Salvador.

The weights and measures in common use in Salvador are the same as in the old Spanish system. The French metric system was introduced in 1885.

St. Domingo.

The old Spanish weights and measures are in general use. The French metric system also is in use.

United States of America.

The British Imperial system of weights and measures is employed in the United States, with the exception of the measures of capacity for dry goods and for liquids, which are the same as the old English measures. The standard U.S. gallon is the same as the old English wine gallon, or 231 cubic inches, capable of holding 8·33888 pounds of pure water of maximum density, at 39·1° F.; or 8⅓ pounds at 62° F. The U.S. gallon is thus 83⅓ per cent. or ⅚ths of the Imperial standard gallon.

The chain for land measurement is 100 feet long, and each foot is divided into tenths.

In City measurements the inch is the unit, divided into tenths.

In mechanical measurements, the inch is the unit, divided into 100 parts.

1 cord of wood is (4 feet × 4 feet × 8 feet) = 128 cubic feet.

In addition to the legalised scale of weights, the same as that of Great Britain and Ireland, there are the Quintal or Centner of 100 pounds; and the New York ton of 2,000 pounds, which is also used in the other States of the Union. These, the Centner and the New York ton, have practically superseded the British hundredweight and ton.

The French metric system of weights and measures has been legalised concurrently with the existing system.

TABLE 69.—AMERICAN STANDARD WIRE-GAUGE.

(Brown and Sharpe's.)

For Sheets and Wire.

Mark.	Size.	Mark.	Size.	Mark.	Size.	Mark.	Size.
	Inch.		Inch.		Inch.		Inch.
4/0	.4600	8	·1285	19	·0359	30	·01003
3/0	·4096	9	·1144	20	·0320	31	·00893
2/0	·3648	10	·1019	21	·0285	32	·00795
0	·3249	11	·0907	22	·0253	33	·00708
1	·2893	12	·0808	23	·0226	34	·00603
2	·2576	13	·0720	24	·0201	35	·00561
3	·2294	14	·0641	25	·0179	36	·00500
4	·2043	15	·0571	26	·0159	37	·00445
5	·1819	16	·0508	27	·0142	38	·00397
6	·1620	17	·0453	28	·0126	39	·00353
7	·1443	18	·0403	29	·0113	40	·00314

TABLE 70.—LIQUID MEASURE (AMERICAN).

		Imperial Gallons.
4 gills	1 pint	
2 pints	1 quart	
4 quarts (231 cubic inches)	1 gallon	·8333
31½ gallons	1 barrel	26·250
63 gallons	1 hogshead	52·50
2 hogsheads	1 pipe, or butt	105·00
2 pipes	1 tun	210·00

TABLE 71.—DRY MEASURE (AMERICAN).

2 pints	1 quart	
4 quarts (268·8025 cubic inches)	1 gallon	·96945 Imperial gallon.
2 gallons	1 peck	1·9388 do. peck
4 pecks	1 struck bushel	·96945 do. bushel

Uruguay.

The French metrical system has been officially adopted; but it is not in general use. The old weights and measures are the same as those of the Argentine Republic. The weights and measures of Brazil are in general use.

Venezuela.

The French metrical system has been legally established. The system in general use is the same as that of Colombia.

West Indies.

The weights and measures are the same as those of the United Kingdom.

Digitiz

MONEY.

Great Britain and Ireland.

		Weight. Grains.
4 farthings 2 halfpence	1 penny	145·833 bronze.
3 pence	1 threepenny piece	21·818 silver.
6 pence	1 sixpence	43·636 ,,
12 pence	1 shilling	87·273 ,,
2 shillings	1 florin	174·545 ,,
2½ shillings	1 half-crown	218·182 ,,
10 shillings	1 half-sovereign	61·6372 gold.
20 shillings	1 sovereign, or pound sterling	123·2745 ,,

Approximate Diameters and Weights.

	Diameter.		Weight.	
1 farthing	·80 inch		$\frac{1}{10}$ ounce.	
1 halfpenny	1·0 ,,		$\frac{1}{5}$,,	
1 penny	1·2 ,,		$\frac{1}{3}$,,	
1 threepenny piece	$\frac{5}{8}$,,		$\frac{1}{20}$,,	
1 sixpence	$\frac{3}{4}$,,		$\frac{1}{10}$,,	
1 shilling	$\frac{29}{32}$,,	or ·90 inch	$\frac{1}{5}$,,	
1 florin	$1\frac{5}{32}$,,	or 1·16 ,,	$\frac{2}{5}$,,	
1 half-crown	$1\frac{1}{4}$,,		$\frac{1}{2}$,,	
1 half-sovereign	$\frac{3}{4}$,,		$\frac{1}{7}$,,	fully.
1 sovereign	$\frac{27}{32}$,,	or ·84 inch	$\frac{2}{7}$,,	fully.

Composition.

Bronze :—Copper, tin, and zinc.
Silver :—Fine silver, 92½ per cent. ; alloy, 7½ per cent.
Gold :—Fine gold, 91⅔ per cent. ; alloy, 8⅓ per cent.

Intrinsic Value.

480 pence equal to £1 sterling.
22 shillings equal to £1 sterling.
Mint price of Standard Gold, £3 17*s.* 10½*d.* per ounce.

France.

Bronze.		Weight.	Diameter.	Equivalent Value. Penny.
1 centime	$\frac{1}{100}$ franc	1 gramme	15 millimetres	·10
2 centimes	$\frac{1}{50}$,,	2 ,,	20 ,,	·20
5 centimes (*sou*)	$\frac{1}{20}$,,	5 ,,	25 ,,	·50
10 centimes (*gros sou*)	$\frac{1}{10}$,,	10 ,,	30 ,,	1·00

Silver.		Weight.	Diameter.	Equivalent Value. Pence.
20 centimes	$\frac{1}{5}$ franc	1 gramme	16 millimetres	2
50 centimes	$\frac{1}{2}$,,	2·5 ,,	18 ,,	4$\frac{3}{4}$
100 centimes	1 ,,	5 ,,	23 ,,	9$\frac{1}{2}$ more exactly 9·524
2 francs .	2 ,,	10 ,,	27 ,,	1*s.* 7*d.*
5 francs .	5 ,,	25 ,,	37 ,,	3*s.* 11$\frac{5}{8}$*d.*

Gold.			£	*s.*	*d.*
5 francs .	1·61290 grammes	17 millimetres		3	11$\frac{5}{8}$
10 francs .	3·22580 ,,	19 ,,		7	11$\frac{1}{4}$
20 francs (napoleon)	6·45161 ,, = 99·56 grains	21 ,,		15	10$\frac{1}{2}$
50 francs .	16·12903 grammes	28 ,,	1	19	8$\frac{1}{5}$
100 francs .	32·25806 ,,	35 ,,	3	19	4$\frac{4}{10}$

The above English values of French coins are calculated at the rate of 25 francs 20 centimes to £1 sterling. The standard fineness of the gold pieces is 90 per cent., with 10 per cent. of copper.

A Monetary Convention exists between France, Belgium, Italy, Switzerland, and Spain, adopting the gold and silver coins above noted.

Germany.

The mark, of 100 pfennigs, is a silver coin of the value of 11$\frac{3}{4}$ pence. The 10-mark gold piece is of the value of 9*s.* 9$\frac{1}{2}$*d.* English money. The 20-mark gold piece is equivalent to 19*s.* 7*d.*; it weighs 122·92 grains. One thaler is nearly equal to 3 marks; it is equal to 3 shillings.

Other Countries in Europe.

Belgium.—The monetary system is the same as that of France.

Denmark.—There is a decimal system of currency. 1 krone = 100 öre. 18 krones = £1.

Greece.—The drachma = 1 franc; and 100 lepta = 1 drachma.

Italy.—The monetary system is the same as that of France. The lira, of 100 centesimi, = 1 franc.

The Netherlands.—The guilder or florin, of 100 cents, = 1*s.* 8*d.* English; or 12 guilders = £1.

Portugal.—The milreis, or 1,000 reis, = 4*s.* 5$\frac{1}{3}$*d.*; about 4$\frac{1}{2}$ milreis = £1; 18$\frac{3}{4}$ reis = 1 penny. One corda (gold coin) = 10,000 reis = £2 4*s.* 5$\frac{1}{2}$*d.*; and weighs 17·735 grammes.

Roumania.—The French decimal monetary system is practised, of which the unit is the leï = 1 franc.

Russia.—The silver rouble = 100 kopecks, is the legal unit of money = 3*s*. 2·054*d*. English. There are three gold coins; the three-rouble, five-rouble, and ten-rouble pieces. The marc of Finland = 1 franc.

Servia.—The French monetary system is adopted. The dinar = 1 franc. The gold milan = 20 francs.

Spain.—The peseta, of 100 centimos, = 1 franc. It is equal to 4 reals, of which there are about 100 to the £1. The 25-peseta piece is 19*s*. 9½*d*. English value.

Sweden, Norway.—The Swedish krona, of 100 ôre, = 1*s*. 1⅓*d*.; or 18 to £1. Norway.—The krone is of the same value as the Swedish krona.

Switzerland.—The French monetary system is legalised. The franc = 10 batzen = 100 rappen.

Turkey.—The lira or gold medjidieh, of 100 piastres, = 18*s*. ·064*d*. The piastre = 2·16*d*.

Malta.

1 scudo of 12 tari = 1*s*. 8*d*. British money is in general circulation. The English sovereign is equal to 12 scudi; the shilling is equal to 7 tari 4 grani (20 grani = 1 taro).

Cyprus.

1 piastra, of 40 para, = 1·4*d*. English. Turkish, English, and French moneys also are in circulation.

Asia.

Ceylon.—The rupee of British India, with cents. The exchange value in 1887 was 1*s*. 6*d*.

China.—The haikwan tael = 10 mace = 100 candereens = 1,000 cash. Rate of exchange in 1887, 5*s*. 0⅛*d*.

Dutch East Indies.—Java.—The guilder, or florin = 100 centen = 1*s*. 8*d*.

Hong Kong.—The Mexican dollar = 100 cents; average rate of exchange, 3*s*. 2*d*. The Chinese tael = 4*s*. 5*d*.

India.—The pie = ½ farthing; 3 pie = 1 pice = 1½ farthing; 4 pice = 1 anna = 1½*d*.; 16 annas = 16 rupee = 2*s*. 15 rupees = 1 gold mohur = 30*s*. 100,000 rupees is a lac of rupees; 10 millions are a crore of rupees.

Japan.—The yen, or dollar, of 100 sens; nominal value, 4*s*.; real value (1887), 3*s*. 4*d*.

Persia.—The krân is 7⅙*d*. = 20 shâhîs; 1 shahi = ·3582*d*.

Siam.—1 tical or bat = 64 atts; rate of exchange, 2*s*. 1*d*.

Straits Settlements.—The legal tenders are, the dollar issued from Her Majesty's Mint at Hong Kong, the silver dollar of

Spain, Mexico, Peru, Bolivia, the American trade dollar, and the Japanese dollar, or yen.

Australasia.—The moneys are the same as those of the United Kingdom.

Africa.

Algeria.—The French monetary system is practised.

Cape Colony.—The English monetary system is practised.

Egypt.—1 piastre (tariff) of 10 dimes or 40 paras = 2·461 pence; 97½ piastres = £1 sterling; 100 piastres = £1 Egyptian = £1 0*s.* 6*d.* 1 piastre (tariff) = 2 piastres (current).

Liberia.—Chiefly British money current.

Madagascar.—The only legalised coin is the silver five-franc piece. The Italian five-lire piece is accepted.

Mauritius.—The Indian rupee is the standard coin.

Morocco.—6 floos = 1 blankeel or muzoona = ·09 penny.
4 blankeels = 1 ounce, or okia = ·38 „
10 ounces = 1 mitkal = 3·08 „

Spanish and French money are current in Morocco.

Tunis.—The piastre, of 16 karubs; average value, 6*d.* Spanish and French money are current in Tunis.

Zanzibar.—The Indian rupee is the coin universally current; though there is a special coinage issued under the authority of the Sultan, of which the dollar is the unit, of equal value with the American coins.

America.

Argentine Republic.—The silver dollar of 100 centesimos; average rate of exchange, 4*s.*

Bolivia.—The boliviano, or dollar of 100 centesimos, struck on the basis of the five-franc piece. Present value (1887), 3*s.* 4*d.*

Brazil.—The milreis of 1,000 reis. Par value, 2*s.* 3*d.*

Canada.—The dollar, of 100 cents; rate of exchange, 4*s.* The value of the English sovereign is by law equal to 4 dollars and 86⅔ cents.

Chili.—The silver peso, of 100 centavos; nominally 1 dollar, but actually coined on the basis of the five-franc piece; value, 3*s.* 4*d.*

Colombia.—The peso or dollar, of 10 reals; actual value, 3*s.* 4*d.*; nominally, 4*s.*

Costa Rica.—The dollar of 100 centavos; nominal value, 4*s.*; present value, 3*s.* 6*d.*

Equador.—The monetary unit is the sueré, equal to a five-franc piece. Average rate of exchange, 36⅓ pence.

Guatemala.—The dollar, or piaster, of 100 centavas; approximate value, 4*s*.

Haiti.—The dollar, or piastre; nominal value, 4*s*.; real value, 3*s*. 4*d*.

Honduras.—The dollar of 100 cents; nominal value, 4*s*.; real value, 3*s*. 4*d*.

Mexico.—The silver peso of 100 cents; nominal value, 4*s*.; real value, 3*s*. 1½*d*.

Nicaragua.—The same as for Honduras.

Paraguay.—The peso, or dollar = 100 centavos; nominal value, 4*s*.; real value, 3*s*.

Peru.—The sole = 100 centesimos; nominal value, 4*s*.; real value, 3*s*. 4*d*.

Salvador.—The peso, or piastre, of 8 reals; approximate value, 4*s*. 3½*d*. The dollar of 100 centavos, 4*s*.

San Domingo.—The same as for Spain.

United States.—The dollar of 100 cents. Par value, 49·32*d*.; or £1 = 4·866 dollars.

Uruguay.—The peso, or dollar, of 100 centevas; approximate value, 4*s*. 3*d*.; or £1 = 4·70 dollars.

Venezuela.—The venezolano of 100 centavas; approximate value, 3*s*. 4*d*. The bolivar = 1 franc.

SPECIFIC GRAVITY, WEIGHT, AND VOLUME.

Density of Alloys and Amalgams.

Messrs. F. Crace-Calvert and Richard Johnson investigated the conductibility of heat, tenacity, hardness, and expansion of alloys and amalgams formed with pure metals, according to the law of equivalents, and that of multiple preparations, the results of which are recorded in Table 72. It was discovered that all alloys of copper, in course of formation, make a contraction of volume; whilst all the amalgams dilate and have less than the mean density calculated in terms of the densities and proportions of the elements. Also that the maximum contraction or dilation of an alloy or an amalgam takes place generally when an equivalent of each metal is taken, except in the case of tin and zinc. These general results are attributable, no doubt, to the fact of all the alloys, except these last-named, being combinations, not mixtures. Some alloys have exceptionally great contraction or dilation. Thus, the alloy of 3 equivalents of copper to 1 of tin, has 8·954 density; calculated as a mixture, its density would only be 8·208. The amalgam of one equivalent of tin with one of mercury dilates by one-tenth of the elementary volumes.

TABLE 72.—METALS: SPECIFIC GRAVITY, WEIGHT, AND VOLUME.

METALS.	Specific Gravity.	Weight of One Cubic Foot.	Cubic Feet per Ton.
	Water = 1.	Pounds.	Cubic Ft.
Aluminium, wrought	2·67	167	13·44
„ cast	2·56	160	14·02
Antimony	6·71	418	5·35
Arsenic	5·80	361·5	6·19
Bismuth	9·90	617	3·63
Brass, cast :—	8·10	505	4·43
75 copper, 25 zinc, sheet	8·45	527	4·25
66 „ 34 „ yellow	8·30	518	4·32
60 „ 40 „ Muntz's metal	8·20	511	4·38
Brass wire	8·55	533	4·20
Bronze :—			
84 copper, 16 tin, gun metal	8·56	534	4·19
83 „ 17 „ „	8·46	528	4·24
81 „ 19 „ „	8·46	528	4·24
79 „ 21 „ mill bearings	8·73	544	4·11
35 „ 65 „ small bells	8·06	503	4·45
21 „ 79 „ „	7·39	461	4·86
15 „ 85 „ speculum metal	7·45	465	4·82
Calcium	1·58	98·5	22·72
Cobalt	8·50	530	4·22
Chromium	6·00	374	5·98
Copper, sheet	8·81	549	4·08
„ hammered	8·92	556	4·02
„ wire	8·88	554	4·04
Gold	19·24	1200	1·87
Iron, cast :—			
white	7·50	468	4·79
grey	7·20	449	4·99
hot blast	6·97	435	5·15
„ 14th melting	7·53	470	4·77
mean, for ordinary calculations	7·22	450	5·00
Iron, wrought :—			
common bar, rails	7·55	471	4·76

TABLE 72.—METALS: SPECIFIC GRAVITY, WEIGHT, AND VOLUME (*continued.*)

METALS.	Specific Gravity.	Weight of One Cubic Foot.	Cubic Feet per Ton.
	Water = 1.	Pounds.	Cubic Ft.
Iron, wrought (*continued*) :—			
puddled slab	7·53 to 7·60	469·5 to 474	4·77 to 4·72
various (Kirkaldy), mean	7·65	477	4·69
Yorkshire bar	7·76	484	4·63
Low Moor plates, thick	7·81	487	4·60
pure iron, by electro-deposit	8·14	508	4·41
mean, for ordinary calculations	7·70	480	4·66
Lead, milled sheet	11·42	712	3·14
„ wire	11·28	704	3·18
Lithium	·59	37	6·08
Magnesium	1·74	108·5	20·63
Manganese	8·00	499	4·49
Mercury	13·60	849	2·64
Nickel, hammered	8·67	541	4·14
„ cast	8·28	516	4·34
Platinum	21·52	1342	1·67
Potassium	·86	53·6	41·65
Silver	10·50	6·55	3·42
Sodium	·97	60·5	37·01
Steel :—			
blistered	7·82	488	4·59
crucible	7·84	489	4·58
cast	7·85	489·3	4·57
Bessemer	7·85	489·6	4·57
for ordinary calculations	7·86	490	4·57
Tin	7·41	462	4·84
Zinc, sheet	7·20	449	4·99
„ cast	6·86	428	5·23

TABLE 73.—DENSITY OF ALLOYS AND AMALGAMS.

(F. Crace-Calvert and R. Johnson.)

I. ALLOYS OF GREATER THAN CALCULATED MEAN DENSITY: WITH CONTRACTION.

ALLOY.	Proportions per cent. by Weight.	Density obtained.	Density calculated.	Difference.
1. *Copper and Tin* (bronze)				
$Cu\ Sn^5$	C 9·73 T 90·27	7·517	7·431	·086
$Cu\ Sn^4$	C 11·86 T 88·14	7·558	7·462	·096
$Cu\ Sn^3$	C 15·21 T 84·79	7·606	7·514	·092
$Cu\ Sn^2$	C 21·21 T 78·79	7·738	7·580	·158
$Cu\ Sn$	C 34·98 T 65·02	7·992	7·805	·187
$Sn\ Cu^2$	T 51·83 C 48·17	8·533	8·059	·474
$Sn\ Cu^3$	T 38·21 C 61·79	8·954	8·208	·746
$Sn\ Cu^4$	T 31·73 C 68·27	8·948	8·306	·642
$Sn\ Cu^5$	T 27·10 C 72·90	8·965	8·374	·591
$Sn\ Cu^{10}$	T 15·68 C 84·32	8·832	8·545	·287
$Sn\ Cu^{15}$	T 11·03 C 88·97	8·825	8·615	·210
$Sn\ Cu^{20}$	T 8·51 C 91·49	8·793	8·634	·159
$Sn\ Cu^{25}$	T 6·83 C 93·17	8·820	8·677	·143
2. *Copper and Zinc* (brass)				
$Zn\ Cu^5$	C 82·95 Z 17·05	8·673	8·453	·220
$Zn\ Cu^4$	C 79·56 Z 20·44	8·650	8·387	·263
$Zn\ Cu^3$	C 74·48 Z 25·52	8·576	8·290	·286

TABLE 73.—DENSITY OF ALLOYS AND AMALGAMS (*continued*).

ALLOY.	Proportions per cent. by Weight.	Density obtained.	Density calculated.	Difference.
2. *Copper and Zinc* (brass) (*continued.*)				
Zn Cu^2	C 66·06 Z 33·94	8·488	8·129	·359
Zn Cu	C 49·32 Z 50·58	7·808	8·319	·511
Cu Zn^2	C 32·74 Z 67·26	7·859	7·489	·370
Cu Zn^3	C 24·64 Z 75·36	7·736	7·334	·401
Cu Zn^4	C 19·57 Z 80·43	7·445	7·237	·208
Cu Zn^5	C 16·30 Z 83·70	7·442	7·174	·208
3. *Copper and Bismuth.*				
Cu Bi		9·634	9·566	·068
4. *Copper and Antimony.*				
Cu Sb		7·990	7·386	·604
5. *Tin and Zinc.*				
Zn Sn^2	Z 21·65 T 78·35	7·274	7·193	·081
Zn Sn	Z 35·60 T 64·40	7·262	7·134	·128
Sn Zn^2	T 47·49 Z 52·51	7·188	7·060	·128
Sn Zn^3	T 37·57 Z 62·43	7·180	7·021	·159
Sn Zn^4	T 31·14 Z 68·86	7·155	6·993	·162
Sn Zn^5	T 26·57 Z 73·43	7·140	6·974	·161
Sn Zn^{10}	T 15·32 Z 84·68	7·135	6·927	·208

TABLE 73.—DENSITY OF ALLOYS AND AMALGAMS (*continued*).

II. ALLOYS AND AMALGAMS OF LESS THAN CALCULATED MEAN DENSITY: WITH DILATATION.

ALLOY.	Proportions per cent. by Weight.	Density obtained.	Density calculated.	Difference.
6. *Mercury and Tin.*				
Hg Sn	M 62·97 T 37·03	10·255	11·259	1·004
Hg Sn^2	M 45·88 T 54·12	9·314	10·180	·866
Hg Sn^3	M 36·18 T 63·82	8·805	9·568	·763
Hg Sn^4	M 29·84 T 70·16	8·510	9·168	·658
Hg Sn^5	M 25·38 T 74·62	8·312	8·885	·573
Hg Sn^6	M 22·08 T 77·92	8·151	8·678	·527
7. *Mercury and Bismuth.*				
Hg Bi	M 48·44 B 51·56	11·208	11·638	·430
Hg Bi^2	M 31·82 B 68·18	10·693	11·007	·314
Hg Bi^3	M 23·86 B 76·14	10·474	10·704	·230
Hg Bi^4	M 19·03 B 80·97	10·350	10·522	·172
Hg Bi^5	M 15·82 B 84·18	10·240	10·410	·170
8. *Mercury and Zinc*		11·304	11·944	·640
9. *Antimony and Bismuth*				
Bi Sb^5	B 24·81 A 75·19	7·271	7·470	·201
Bi Sb^4	B 29·20 A 70·80	7·370	7·606	·235
Bi Sb^3	B 35·48 A 64·52	7·561	7·801	·240
Bi Sb^2	B 45·21 A 54·79	7·829	8·102	·273
Bi Sb	B 62·26 A 37·94	8·364	8·630	·268

TABLE 73.—DENSITY OF ALLOYS AND AMALGAMS (*continued*).

ALLOY.	Proportions per cent. by Weight.	Density obtained.	Density calculated.	Difference.
9. *Antimony and Bismuth (continued).*				
Sb Bi^{2}	A 23·26 B 76·74	8·859	9·077	·218
Sb Bi^{3}	A 16·81 B 83·19	9·095	9·277	·182
Sb Bi^{4}	A 13·17 B 86·83	9·276	9·391	·119
Sb Bi^{5}	A 10·82 B 89·18	9·369	9·464	·095
10. *Bismuth and Zinc.*				
Bi Zn		9·046	9·132	·086
11. *Tin and Lead.*				
Pb Sn^{5}	L 26·03 T 73·97	8·093	8·367	·254
Pb Sn^{4}	L 30·57 T 69·43	8·196	8·548	·352
Pb Sn^{3}	L 36·99 T 63·01	8·418	8·823	·405
Pb Sn^{2}	L 46·82 T 53·18	8·774	9·232	·458
Pb Sn	L 63·78 T 36·22	9·458	9·938	·480
Sn Pb^{2}	T 22·11 L 77·89	10·105	10·525	·420
Sn Pb^{3}	T 15·91 L 84·09	10·421	10·783	·362
Sn Pb^{4}	T 12·43 L 87·57	10·587	10·927	·340
Sn Pb^{5}	T 10·20 L 89·80	10·751	11·017	·266
12. *Lead and Antimony.*				
Sb Pb^{5}	A 11·08 L 88·92	10·556	10·919	·363
Sb Pb^{4}	A 13·48 L 86·52	10·387	10·805	·418
Sb Pb^{3}	A 17·20 L 82·80	10·136	10·629	·493

TABLE 73.—DENSITY OF ALLOYS AND AMALGAMS (*continued*).

ALLOY.	Proportions per cent. by Weight.	Density obtained.	Density calculated.	Difference.
12. *Lead and Antimony* (*continued*).				
Sb Pb^2	A 23·68 L 76·32	9·723	10·321	·598
Sb Pb	A 38·39 L 61·61	8·953	9·624	·671
Pb Sb^2	L 44·53 A 55·47	8·330	8·959	·629
Pb Sb^3	L 34·86 A 65·14	7·830	8·355	·525
Pb Sb^4	L 28·64 A 71·36	7·525	8·059	·534
Pb Sb^5	L 24·31 A 75·69	7·432	7·854	·422

TABLE 74.—STONES: SPECIFIC GRAVITY, WEIGHT AND VOLUME.

STONES.	Specific Gravity.	Weight of one Cubic Foot.	Cubic Feet per Ton.
	Water = 1.	Pounds.	Cubic Ft.
Alabaster, calcareous	2·76	172·1	13·0
„ gypseous	2·31	144·0	15·6
Barytes	4·45	277·5	8·07
Basalt	2·45 to 3·00	152·8 to 187·1	14·7 to 12·0
Chalk, air-dried	2·50	155	14·5
Diamond	3·50	...	...
Flint	2·63	164	13·7
Felspar	2·60	162·1	13·8
Gneiss	2·69	168	13·3
Granite	25·0 to 27·4	156 to 171	14·4 to 13·1
Graphite	2·20	137·2	16·3
Jasper	2·72	169·7	13·2
Lias	2·25 to 2·45	140·3 to 152·8	16·0 to 14·7
Limestone	1·86 to 2·53	116 to 158	19·3 to 14·2

TABLE 74.—STONES: SPECIFIC GRAVITY, WEIGHT AND VOLUME (*continued*).

STONES.	Specific Gravity.	Weight of one Cubic Foot.	Cubic Feet per Ton.
	Water = 1.	Pounds.	Cubic Ft.
Marble :—			
African	2·80	174·6	12·8
British	2·71	169·0	13·3
Carrara	2·72	169·6	13·2
Egyptian green	2·67	166·5	13·5
Florentine	2·52	157·1	14·3
French	2·65	165·2	13·6
Mica	2·93	183	12·2
Oolitic stones	1·89 to 2·60	118 to 162	19·0 to 13·8
Ores :—			
Spicular or red iron ore	5·21	327·4	6·84
Magnetic iron ore	5·09	317·6	7·05
Brown iron ore	3·92	244·6	9·16
Spathic iron ore	3·83	238·8	9·38
Clydesdale iron ore	3·05	190·5	11·76
Potter's stone	2·80	174·6	12·8
Quartz	2·61 to 2·71	162·8 to 169	13·8 to 13·3
,, broken up and heaped	1·96	122	20
,, quarry débris	1·47	91·4	24·5
Rock crystal	2·65	165·4	13·6
Sandstone	2·04 to 2·70	127 to 168	17·6 to 13·3
Serpentine	2·81	175·2	12·8
Slate	2·60 to 2·85	162·1 to 177·7	13·8 to 12·6
Talc, steatite	2·70	168·4	13·3
Trap, touchstone	2·72	169·6	13·2
ARTIFICIAL STONES.			
Apoenite :—Ransom's silicious stone (silica, soda, water)	1·60	99·7	22·5
Concrete :—			
Portland cement 1, and shingle 10	2·23	139	16·1
Portland cement, rubble, and sand	2·17 to 2·25	135 to 140	16·6 to 16·0

TABLE 74.—STONES: ARTIFICIAL STONES (*continued*).

Concrete :—(*continued*).			
Portland cement 1, and sand 2	2·04	127	17·6
Roman cement 1, and sand 2	1·92	120	18·7
Victoria stone (crushed granite, Portland cement, silica)	2·31	144	15·6

TABLE 75.—WEIGHT AND COMPOSITION OF BUILDING STONES.

(Gwilt.)

STONES.	Weight of One Cubic Foot.
1. GRANITES.	Pounds.
Stirling Hill, Stirling	165·9
High Rock, Breadalbane	166·0
Black Hill, Stirling	166·6
Dalkey, Dublin	169·6
Bars, Breadalbane	169·7
Haytor, Devonshire	165·2
Blue Penmaenmaur, Carnarvonshire	160·1
Aberdeen Grey, Aberdeenshire	166·5
„ Red „	165·3
Cornish Grey, Cornwall	166·7
„ Red „	164·0
Average	166·0
2. LIMESTONES.	
Beer, Devonshire	131·7
Chilmark, Wiltshire	153·4
Hopton Wood, Derbyshire	158·4
Sea Combe, Dorsetshire	151·0
Sutton, Glamorganshire	136·0
Tottenhoe, Bedfordshire	116·5
Average	141·2
3. MAGNESIAN LIMESTONES.	
Bolsover, Denbigh	151·7
Broadsworth, Yorkshire	133·6
Cadeby „	126·6

TABLE 75.—WEIGHT AND COMPOSITION OF BUILDING STONES (*continued*).

STONES.	Weight of One Cubic Foot.
3. MAGNESIAN LIMESTONES (*continued*).	
Huddlestone ,,	137·8
Roche Abbey ,,	139·1
Smawes ,,	127·5
Average	136·0
4. OOLITIC STONES.	
Ancaster, Lincolnshire	139·2
Barnack Mill, Northamptonshire	136·7
Bath Lodge Hill, Somersetshire	116·0
Bath Baynton ,,	123·0
Bath (Drew's Quarry) ,,	122·6
Cranmore, Wiltshire	134·2
Haydon, Lincolnshire	138·5
Ketton, Rutlandshire	128·3
Portland	126·8 to 147·6
Taynton, Oxon	135·9
Wass, Yorkshire	soft, 141·7 hard, 162·5
Windrush, Gloucestershire	soft, 118·1 hard, 135·9
Average	133·5
5. SANDSTONES.	
Abercarne, Monmouth	167·9
Barbadoes, Tintern, Monmouth	146·7
Binnie, Linlithgowshire	140·1
Bolton's Quarry, Yorkshire	126·7
Bramley Fall ,,	142·2
Calverley, Kent	118·1
Craigleith, Edinburgh	145·9
Craw Bank, Linlithgowshire	129·1
Duffield, Derbyshire	132·9
Duke's Quarries, Derbyshire	144·5
Elland Edge, Yorkshire	153·2
Gatherley Moor ,,	135·8
Gatton, Surrey	103·1
Glammis, Forfarshire	161·1
Heddon, Northumberland	130·7
Hollington, Staffordshire	133·1
Humbie, Linlithgow	white, 140·2 grey, 135·8

TABLE 75.—WEIGHT AND COMPOSITION OF BUILDING STONES (*continued.*)

STONES.	Weight of One Cubic Foot.
5. SANDSTONES (*continued*).	
Longannet, Perthshire	131·7
Munlochy, Ross-shire	160·6
Mylnefield, Perthshire	160·0
Park Spring, Yorkshire	151·1
Pensher, Durham	134·3
Pyot Dykes, Forfarshire	162·5
Scotgate, Yorkshire	158·0
Stancliff, Derbyshire	148·2
Stenton, Durham	142·5
Whitby Company's, Aislaby, Yorkshire	126·7
„ Egton „	127·9
„ Sneaton „	134·8
„ Newton Dale „	134·7
Average	140·5
6. MARBLES.	
Black, Kilkenny	171·4
Tiree, Hebrides	172·3
Carrara (Statuary), Tuscany	168·6
„ Ravaccione	169·1
Ipplepen, Devonshire	163·4
Average	169·0

General Composition of the above Stones.

STONES.	Carbonate of Lime.	Mag-nesia.	Silica.	Iron, Alumina, Water, and Loss.	Total.
	Per cent.	Pr.cent.	Pr.cent.	Per cent.	
Limestones	81·0	4·2	5	9·8	100·0
Do. Magnesian	54·6	40·6	2	2·8	100·0
Oolitic Stones	94·0	2·7	...	3·3	100·0
Sandstones	1·1	...	95·5	3·4	100·0
Marbles	lime 56·5 carbonic acid 43·0	...	...	water ·5	100·0

TABLE 77.—MINERAL SUBSTANCES, VARIOUS: SPECIFIC GRAVITY, WEIGHT, AND VOLUME (*continued*).

SUBSTANCE.	Specific Gravity.	Weight of One Cubic Foot.	Cubic Foot per Ton.
	Water=1.	Pounds.	Cubic Ft.
Mud :—			
Dry, close	1·28 to 1·93	80 to 110	28·0 to 20·4
Wet, moderately pressed	1·93 to 2·09	110 to 130	20·4 to 17·2
Wet, fluid	1·67 to 1·92	104 to 120	21·5 to 18·7
Phosphorus	1·77	110·4	20·3
Plaster	1·57	98	22·9
Portland cement	1·25 to 1·51	78 to 94	28·7 to 23·8
Potash	2·10	131	17·1
Sand	1·44 to 1·87	90 to 117	24·9 to 19·1
„ saturated with water	1·89 to 2·07	118 to 129	19 to 17·4
Salt, common	1·92	119·7	18·7
„ rock	2·10 to 2·26	131 to 140·7	17·1 to 15·9
Sulphur	2·00	124·7	18·0
Tiles	2·00	124·7	18·0

TABLE 77*a*.—FUELS IN FRANCE.

	Weight of one Cub. Ft.	Specific Gravity.
	Pounds.	Water=1.
Pure graphite	145·3	2·33
Anthracite	83·5 to 91·0	1·34 to 1·46
Rich coal with a long flame	79·8 to 84·8	1·28 to 1·36
Dry coal with a long flame	84·8	1·36
Rich and hard coal	82·3	1·32
Smithy coal	79·8 to 81·1	1·28 to 1·30
Lignite	77·9 to 84·2	1·25 to 1·35
„ bituminous	72·3 to 74·8	1·16 to 1·20
„ imperfect	81·7	1·31
Bitumen, red	72·3	1·16
„ black	66·7	1·07
„ brown	51·7	0·83
Asphalte	66·1	1·06

TABLE 78.—WEIGHT AND VOLUME IN BULK OF VARIOU SOLIDS.

(Tredgold.)

SUBSTANCE.	Weight of One Cubic Foot in bulk.	Volume of One Ton in bulk.
	Pounds.	Cubic Feet.
Lead, cast in pigs	567	4
Iron, cast in pigs	360	6·25
Limestone or Marble, in blocks	172	13
Granite, Aberdeen, in blocks	166	13·5
,, Cornish, ,,	164	14
Sandstone, in blocks	141	16
Portland Stone, in blocks	132	17
Potter's Clay	130	17
Loam or Strong Soil	126	18
Bath Stone, in blocks	123·5	18
Gravel	109	21
Sand	95	23·5
Bricks, Common Stock, dry	93	24
Culm	63	36
Water, River	62·5	36
Splint Coal	57	39·5
Oak, Seasoned	52	43
Coal (Newcastle) caking	50	45
Wheat	48	47
Barley	38	59
Red Fir	38	59
Hay, compact, old	8	280

TABLE 79.—MEASURES OF ORES, EARTH, &C.

(Rand Drill Company.)

		Weight.
14·5	Cubic Feet of ordinary Gold or Silver Ore, in mine	1 ton
22	,, of Broken Quartz	1 ,,
20	,, Gravel, in bank	1 ,,
30	,, Gravel, when dry	1 ,,
28	,, Sand	1 ,,
20	,, Earth, in bank	1 ,,
30	,, ,, ,, when dry	1 ,,
19	,, Clay	1 ,,
45	,, Bituminous Coal, heaped	1 ,,
42	,, Anthracite ,,	1 ,,
123	,, Charcoal ,,	1 ,,
71	,, Coke ,,	1 ,,

	Weight.
1 Cubic Foot Anthracite, heaped . .	50 lb. to 55 lb.
1 ,, Bituminous Coal ,, . . .	45 lb. to 55 lb.
1 ,, Cumberland Coal	53 lb.
1 ,, Cannel Coal	50¼ lb.
1 ,, Hardwood Charcoal . .	18½ lb.
1 ,, Pine Charcoal . . .	18 lb.

	Weight.	Equivalent as Fuel to
1 Cord of Wood, 4 feet × 4 feet × 8 feet	.	= 128 cubic feet.
1 Cord of air-dried Hickory or Hard Maple . .	4,500 lb.	2,000 lb. coal.
1 ,, ,, White Oak . .	3,850 ,,	1,715 ,,
1 ,, ,, Beech, Red Oak or Black Oak .	3,250 ,,	1,450 ,,
1 ,, ,, Poplar (white wood), Chestnut, or Elm .	2,350 ,,	1,050 ,,
1 ,, ,, Average Pine .	2,000 ,,	925 ,,

TABLE 80.—FUELS: SPECIFIC GRAVITY, WEIGHT, AND BULK.

FUELS.	Specific Gravity.	Weight of One Cubic Foot.		Volume of One Ton, heaped.
		Solid.	Heaped.	
	Water = 1.	Lbs.	Lbs.	Cub. Ft.
COALS.				
Anthracite	1·37	85·4	58·3	38·4
,, American . .	1·30 to 1·84	93·5	54·0	...
Welsh	1·32	82·3	53·1	42·7
Newcastle	1·25	78·3	49·8	45·3
Derbyshire and Yorkshire .	1·29	79·6	45·9	47·4
Lancashire	1·27	79·4	49·7	45·2
Scotch	1·26	78·6	50·0	42·0
Irish: Slievardagh anthracite	1·59	99·6	62·8	35·7
Bituminous coal, American	1·35	84·0	50·0	...
Boghead (Scotland) . .	1·18	...	...	...
COKE.				
Coke, generally . . .	...	40 to 50	30·0	70 to 80
Tanfield	·74	46	30·0	74·7

TABLE 80.—FUELS: SPECIFIC GRAVITY, WEIGHT, AND BULK (*continued*).

FUELS.	Specific Gravity.	Weight of One Cubic Foot.		Volume of One Ton, heaped.
		Solid.	Heaped.	
	Water=1.	Lbs.	Lbs.	Cub. Ft.
COKE (*continued*).				
Gas coke	...	...	23·8 to 28·6	...
American	...	...	32·1	69·8
Seraing (France)	...	...	31·0	72·0
Graphite	2·33	145·3	...	...
LIGNITE AND ASPHALTE.				
Perfect lignite	1·29	...	...	...
Imperfect lignite	1·15	...	...	...
Bituminous lignite	1·18	...	...	...
Asphalte	1·06	...	...	...
WOOD.—*See* Table 81.				
WOOD CHARCOAL. *As made, heaped.*	Heaped.			
Oak and beech	·24 to ·25	...	15 to 15·6	...
Birch	·22 to ·23	...	13·7 to 14·3	...
Pine	·20 to ·21	...	12·5 to 13·1	...
Average	·225	...	14	...
In small pieces, heaped.				
Walnut	·63	...	39·3	...
Ash	·53	...	34·3	...
Beech	·52	...	32·5	...
Yoke-Elm	·46	...	28·7	...
Appleton	·46	...	28·7	...
White oak	·42	...	26·2	...
Cherry tree	·41	...	25·6	...
Birch	·36	...	22·5	...
Elm	·36	...	22·5	...
Yellow pine	·33	...	20·6	...
Chestnut tree	·28	...	17·5	...
Poplar	·25	...	15·6	...
Cedar	·24	...	15·0	...
Average	·405	...	25·3	..

TABLE 80.—FUELS: SPECIFIC GRAVITY, WEIGHT, AND BULK (*continued*).

FUELS.	Specific Gravity.	Weight of One Cubic Foot.		Volume of One Ton, heaped.
		Solid.	Heaped.	
	Water = 1.	Lbs.	Lbs.	Cub. Ft.
As Powder.				
Willow	1·55	...	96·7	...
Oak	1·53	...	95·4	...
Alder	1·49	...	92·9	...
Lime tree	1·46	...	91·0	...
Poplar	1·45	...	90·4	...
Average	1·50	...	93·5	...
Gunpowder, loose	·90	...	...	...
" shaken	1·00	...	...	...
" solid	1·55 to 1·80	...	...	...
Irish Peat.				
Very light, spongy, surface peat	·22 to ·34	13·7 to 21·0	...	...
Light surface peat	·34 to ·41	20·9 to 25·3	...	...
Rather dense	·48 to ·67	29·7 to 41·7	...	...
Very dense, dark brown	·65 to ·71	40·5 to 44·5	...	...
Very dense, blackish brown, compact	·72 to ·98	45·1 to 61·3	...	...
Exceedingly dense, jet black	·73 to ·99	53·2 to 61·8	...	...
Exceedingly dense, dark blackish brown	1·05	66·0	...	...
Upper moss	...	...	6·06 to 8·81	369·6 to 254·2
Brown	...	...	15·13	147·0
Compact black	...	...	17·06	131·3
Densest black	...	...	22·54	99·4
Condensed peat	1·0 to 1·3	62·5 to 81·1	43·7 to 56·8	51·2 to 40·0

TABLE 81.—WOODS: SPECIFIC GRAVITY AND WEIGHT.

Wood.	Specific Gravity.	Weight of One Cubic Foot.
	Water=1.	Pounds.
Acacia	·82	51·1
„ with 20 per cent. moisture	·72	44·9
Alder tree	·56	34·9
„ with 20 per cent. moisture	·60	37·4
Ash	·84	52·4
„ with 20 per cent. moisture	·70	43·7
Aspen tree	·60	37·4
Apple tree	·73	45·5
Bamboo	·31 to ·40	19·5 to 24·9
Beech	·75 to ·85	46·8 to 50·3
„ with 20 per cent. moisture	·82	51·1
„ cut one year	·66	41·2
Birch	·72 to ·74	44·9 to 46·1
Boxwood	1·04	64·8
Cedar of Lebanon	·49 to ·57	30·6 to 35·5
Cork	·24	15·0
Cypress, cut one year	·66	41·2
Ebony	1·13	70·5
„ Green	1·21	75·5
„ Black	1·19	74·2
Elder pith	·076	4·74
Elm	·55	34·3
„ Green	·76	47·5
„ with 20 per cent. moisture	·72	44·9
Fir, Norway Pine	·74	46·1
„ Red Pine	·48 to ·70	29·9 to 43·7
„ Spruce	·48 to ·70	29·9 to 43·7
„ Larch	·50 to ·64	31·2 to 39·9
„ White Pine, English	·55	34·3
„ „ Scotch	·53	34·3
„ „ „ with 20 per cent. moisture	·49	30·6
„ Yellow Pine	·66	41·2
„ „ American	·46	28·7
Hawthorn	·91	56·7
Holly	·76	47·5
Hornbeam	·76	47·5
Laburnum	·92	57·4
Lance Wood	·67 to 1·01	41·8 to 63·0
Lignum-Vitæ	·65 to 1·33	40·5 to 82·9

TABLE 80.—FUELS: SPECIFIC GRAVITY, WEIGHT, AND BULK (*continued*).

Fuels.	Specific Gravity.	Weight of One Cubic Foot.		Volume of One Ton, heaped.
		Solid.	Heaped.	
	Water = 1.	Lbs.	Lbs.	Cub. Ft.
As Powder.				
Willow	1·55	...	96·7	
Oak	1·53	...	95·4	...
Alder	1·49	...	92·9	...
Lime tree	1·46	...	91·0	...
Poplar	1·45	...	90·4	...
Average	1·50	...	93·5	
Gunpowder, loose	·90			
,, shaken	1·00	...	...	
,, solid	1·55 to 1·80		...	...
Irish Peat.				
Very light, spongy, surface peat	·22 to ·34	13·7 to 21·0		
Light surface peat	·34 to ·41	20·9 to 25·3	...	
Rather dense	·48 to ·67	29·7 to 41·7	...	
Very dense, dark brown	·65 to ·71	40·5 to 44·5	...	...
Very dense, blackish brown, compact	·72 to ·98	45·1 to 61·3	...	
Exceedingly dense, jet black	·73 to ·99	53·2 to 61·8	...	
Exceedingly dense, dark blackish brown	1·05	66·0	...	
Upper moss	...	...	6·06 to 8·81	369·6 to 254·2
Brown	...	...	15·13	147·0
Compact black	...	...	17·06	131·3
Densest black	...	...	22·54	99·4
Condensed peat	1·0 to 1·3	62·5 to 81·1	43·7 to 56·8	51·2 to 40·0

TABLE 81.—WOODS: SPECIFIC GRAVITY AND WEIGHT.

Wood.	Specific Gravity.	Weight of One Cubic Foot.
	Water = 1.	Pounds.
Acacia	·82	51·1
,, with 20 per cent. moisture	·72	44·9
Alder tree	·56	34·9
,, with 20 per cent. moisture	·60	37·4
Ash	·84	52·4
,, with 20 per cent. moisture	·70	43·7
Aspen tree	·60	37·4
Apple tree	·73	45·5
Bamboo	·31 to ·40	19·5 to 24·9
Beech	·75 to ·85	46·8 to 50·3
,, with 20 per cent. moisture	·82	51·1
,, cut one year	·66	41·2
Birch	·72 to ·74	44·9 to 46·1
Boxwood	1·04	64·8
Cedar of Lebanon	·49 to ·57	30·6 to 35·5
Cork	·24	15·0
Cypress, cut one year	·66	41·2
Ebony	1·13	70·5
,, Green	1·21	75·5
,, Black	1·19	74·2
Elder pith	·076	4·74
Elm	·55	34·3
,, Green	·76	47·5
,, with 20 per cent. moisture	·72	44·9
Fir, Norway Pine	·74	46·1
,, Red Pine	·48 to ·70	29·9 to 43·7
,, Spruce	·48 to ·70	29·9 to 43·7
,, Larch	·50 to ·64	31·2 to 39·9
,, White Pine, English	·55	34·3
,, ,, Scotch	·53	34·3
,, ,, ,, with 20 per cent. moisture	·49	30·6
,, Yellow Pine	·66	41·2
,, ,, American	·46	28·7
Hawthorn	·91	56·7
Holly	·76	47·5
Hornbeam	·76	47·5
Laburnum	·92	57·4
Lance Wood	·67 to 1·01	41·8 to 63·0
Lignum-Vitæ	·65 to 1·33	40·5 to 82·9

TABLE 81.—WOODS: SPECIFIC GRAVITY AND WEIGHT (*continued*).

WOOD.	Specific Gravity.	Weight of One Cubic Foot.
	Water=1.	Pounds.
Mahogany, Spanish	·85	53·0
,, St. Domingo	·75	46·8
,, Cuba	·56	34·9
,, Honduras	·56	34·9
Maple	·65	40·5
,, 20 per cent. moisture	·67	41·8
Mulberry	·89	55·5
Oak, Heart of	1·17	73·0
,, English	·93	58·0
,, European	·69 to ·99	43·0 to 61·7
,, American Red	·87	54·2
Olive tree	·68	42·4
Orange tree	·71	44·3
Pear tree	·73	45·5
Plane tree	·65	40·5
Plum tree	·87	54·2
Pomegranate	1·35	84·2
Poplar	·39	24·3
,, White	·32 to ·51	20·0 to 31·8
,, 20 per cent. moisture	·48	29·9
Rosewood	1·03	64·2
Rock-Elm	·80	50·0
Satin-wood	·96	59·9
Service tree	·67	41·8
Sycamore	·59	36·8
Teak, African	·98	61·0
Vine tree	·60	37·4
Walnut, Green	·92	57·4
,, Brown	·68	42·4
Willow	·49	30·6
Yew	·74 to ·81	46·1 to 50·5
Yoke Elm, with 20 per cent. moisture	·76	47·5
INDIAN WOODS (Berkley).		
Khair	1·17	73
Red Eyne	1·09	68
Erroul	1·01	63
Bibla	·90	56

TABLE 81.—WOODS: SPECIFIC GRAVITY AND WEIGHT (*continued*).

Wood.	Specific Gravity.	Weight of One Cubic Foot.
	Water=1.	Pounds.
INDIAN WOODS (*continued*).		
Blackwood	·90	56
Northern Teak	·88	55
Southern Teak	·77	48
Jungle Teak	·66	41
Kullum	·66	41
Hedoo	·63	39
Poon	·63	39
BRITISH GUIANA (Fowke).		
Sipiri, or Green Heart	1·05 to 1·09	65·5 to 68·0
Wallaba	1·04	64·8
Brown Ebony	1·03	64·2
Letter Wood	1·00	62·4
Cuamara, or Tonka	·99	61·7
Monkey Pot	·94	58·6
Mora	·92	57·4
Ducaballi	·91	56·7
Cabacalli	·89	55·5
Kaieeballi	·87	54·2
Sirabuliballi	·84	52·4
Buhuradda	·81	50·5
Buckati	·81	50·5
Houbaballi	·81	50·5
Baracara	·81	50·5
White Cedar	·77	48·0
Locust tree	·71	44·3
Cartan	·70	43·7
Purple Heart	·68	42·4
Bartaballi	·64	39·4
Crabwood	·60	37·4
Silverballi	·55	34·3
JAMAICA (Fowke).		
Black Heart Ebony	1·19	74·2
Lignum-Vitæ	·65 to 1·17	40·5 to 73·0
Small Leaf	1·17	73·0
Neesberry Bullet tree	1·05	65·5
Red Bully tree	1·00	62·4
Iron Wood	·99	61·7
Sweet Wood	·97	60·5

TABLE 81.—WOODS: SPECIFIC GRAVITY AND WEIGHT (*continued*).

Wood.	Specific Gravity.	Weight of One Cubic Foot.
	Water = 1.	Pounds.
JAMAICA (*continued*).		
Fustic	·97	60·5
Satin Candlewood	·96	59·9
Bastard Cabbage Bark	·94	58·6
White Dogwood	·94	58·6
Black ,,	·93	58·0
Gynip	·93	58·0
Wild Mahogany	·92	57·4
Cashaw	·92	57·4
Wild Orange	·85 to ·91	53·0 to 56·7
Sweet Orange	·79	49·3
Bullet tree (bastard)	·90	56·1
Tamarind	·87	54·2
,, wild	·75	46·8
Prune	·86	53·6
Yellow Sanders	·86	53·6
Beech	·84	52·4
French Oak	·77	48·0
Broad Leaf	·77	48·0
Fiddlewood	·71	44·3
Prickle Yellow	·69	43·0
Boxwood	·69	43·0
Locust tree	·68	42·4
Lance Wood	·68	42·4
Green Mahogany	·66	41·2
Yacca	·63	39·3
Cedar	·58	36·2
Calabash	·56	34·9
Bitter Wood	·55	34·3
Blue Mahoe	·54	33·7
NEW SOUTH WALES.		
Box of Ilwarra	1·17	73·0
,, Bastard	1·12	69·8
,, True, of Camden	·97	60·5
Mountain Ash	1·11	69·2
Kakaralli	1·10	68·6
Iron Bark	1·03	64·2
,, broad leaved	1·02	63·6
Woolly Butt	1·01	63·0
Black ,,	·89	55·5

TABLE 81.—WOODS: SPECIFIC GRAVITY AND WEIGHT (*continued*).

Wood.	Specific Gravity.	Weight of One Cubic Foot.
	Water = 1.	Pounds.
NEW SOUTH WALES (*continued*).		
Water Gum	1·00	62·4
Blue Gum	·84	52·4
Cog Wood	·96	59·9
Mahogany	·95	59·2
„ Swamp	·86	53·6
Gray Gum	·93	58·0
Stringy Bark	·86	53·6
Hickory	·75	46·8
Forest Swamp Oak	·66	41·2

TABLE 82.—ANIMAL SUBSTANCES: SPECIFIC GRAVITY AND WEIGHT.

(Claudel.)

Substance.	Specific Gravity.	Weight of One Cubic Foot.
	Water = 1.	Pounds.
Pearls	2·72	169·6
Coral	2·69	167·7
Ivory	1·82 to 1·92	114 to 119·7
Bone	1·80 to 2·00	112·2 to 124·7
Wool	1·61	100·4
Tendon	1·12	69·8
Cartilage	1·09	68·0
Crystalline humour	1·08	67·3
Human Body	1·07	66·7
Nerve	1·04	64·9
Bees Wax	·96	59·9
Lard	·95	59·3
Spermaceti	·94	58·8
White of Whalebone	·94	58·7
Butter	·94	58·7
Pork Fat	·94	58·7
Tallow	·92	57·5
Beef Fat	·92	57·5
Mutton Fat	·92	57·4
Animal Charcoal, in heaps	·80 to ·83	50 to 52

TABLE 83.—VEGETABLE SUBSTANCES: SPECIFIC GRAVITY AND WEIGHT.

SUBSTANCE.	Specific Gravity.	Weight of One Cubic Foot.
	Water = 1.	Pounds.
Cotton	1·95	121·6
Flax	1·79	111·6
Starch	1·53	95·4
Fecula	1·50	93·5
Gum, Arabic	1·45	...
,, Mastic	1·07	66·7
Resin, Guayacum	1·20	74·8
,, Benzoin	1·09	68·0
Indigo	1·009	...
Sugar	1·005	...
Amber	1·09	68·0
Gutta-percha	·97	60·5
India-rubber	·93	58·0
	Weight of One Cubic Foot, loosely filled.	Weight of One Cubic Foot, closely filled.
Grain:—		
Wheat, Red Winter	49	53½
,, Bombay	49	53
,, California	49	53
,, Walla-Walla	46	50½
,, Bessarabia	49	53
Peas, American	50	54
Indian Corn, White American	43½	47
,, Mixed	44	47
Oats, Russian	28	33
Beans, Egyptian	46	50
Barley, English	39	44

Note.—Under the Corn Returns Act, 1882, the bushel of the following grains is, for statistical purposes, to be taken respectively:—

For Wheat as	60 lb.
For Barley as	50 lb.
For Oats as	39 lb.

TABLE 84.—LIQUIDS:—SPECIFIC GRAVITY AND WEIGHT.

LIQUIDS AT 32° F.	Specific Gravity.	Weight of One Cubic Foot.	Weight of One Gallon.
	Water=1.	Pounds.	Pounds.
Mercury	13·596	848·7	136·0
Sulphuric Acid, maximum concentration	1·84	114·9	18·4
Nitrous Acid	1·55	96·8	15·5
Chloroform	1·53	95·5	15·3
Nitric acid, of commerce . .	1·22	76·2	12·2
Acetic acid, maximum concentration . . .	1·08	67·4	10·8
Milk	1·03	64·3	10·3
Sea Water, ordinary . . .	1·026	64·05	10·3
Pure Water, at 39·0° F. . .	1·000	62·425	10·0112
Wine, Red	·99	62·0	9·9
Oil, Linseed	·94	58·7	9·4
„ Rapeseed	·92	57·4	9·2
„ Whale	·92	57·4	9·2
„ Olive	·915	57·1	9·15
„ Turpentine	·87	54·3	8·7
Tar	1·00	62·4	10·0
Petroleum	·88	54·9	8·8
Naphtha	·85	53·1	8·5
Ether, Nitric	1·11	69·3	11·1
„ Sulphurous	1·08	67·4	10·8
„ Nitrous	·89	55·6	8·9
„ Acetic	·89	55·6	8·9
„ Hydrochloric . . .	·87	54·3	8·7
„ Sulphuric	·72	44·9	7·2
Alcohol, proof spirit . . .	·92	57·4	9·2
„ pure	·79	49·3	7·9
Benzine	·85	53·1	8·5
Proof Spirit	·80	49·9	8·0

TABLE 85.—WEIGHT AND SPECIFIC GRAVITY OF OILS.

(Stilwell.)

OILS AT 39° F.	Weight of One Gallon.	Specific Gravity.
	Pounds.	Water = 1.
Sperm, bleached, winter	8·81	·881
„ natural, winter	8·81	·881
Elaine	9·01	·901
Red, saponified	9·02	·902
Palm	9·05	·905
Tallow	9·14	·914
Neatsfoot	9·14	·914
Rape-seed, white, winter	9·14	·914
Olive, light greenish yellow	9·14	·914
„ dark green	9·14	·914
Peanut	9·15	·915
Olive, virgin, very light yellow	9·16	·916
Rape-seed, dark yellow	9·17	·917
Olive, virgin, dark clear yellow	9·17	·917
Lard, winter	9·17	·917
Sea Elephant	9·20	·920
Tanner's Cod	9·20	·920
Cotton-seed, raw	9·22	·922
„ refined, yellow	9·23	·923
Salad (cotton-seed)	9·23	·923
Labrador (cod)	9·24	·924
Poppy	9·24	·924
Seal, natural	9·25	·925
Cocoanut	9·25	·925
Whale, natural, winter	9·25	·925
„ bleached, winter	9·26	·926
Codliver, pure	9·27	·927
Seal, racked	9·29	·929
Cotton-seed, white, winter	9·29	·929
Straits (cod)	9·29	·929
Menhaden, dark	9·29	·929
Linseed (raw)	9·30	·930
Bank (cod)	9·32	·932
Menhaden, light	9·32	·932
Porgy	9·33	·933
Linseed, boiled	9·41	·941
Castor, pure cold pressed	9·67	·967
Rosin, third run	9·89	·989

TABLE 86.—GASES AND VAPOURS.—SPECIFIC GRAVITY, WEIGHT, AND VOLUME.

GASES at 32° F., and under one Atmosphere of Pressure.	Specific Gravity.	Weight of One Cubic Foot.		Volume of One Pound Weight.
	Air = 1.	Pounds.	Ounces.	Cub. Ft.
Mercury	6·9740	·563	9·008	1·776
Chloroform	5·3000	·428	6·846	2·337
Turpentine	4·6978	·378	6·042	2·637
Acetic Ether	3·0400	·245	3·927	4·075
Benzine	2·6943	·217	3·480	4·598
Sulphuric Ether	2·5860	·209	3·340	4·790
Chlorine	2·4400	·197	3·152	5·077
Sulphurous Acid	2·2470	·1814	2·902	5·513
Alcohol	1·6130	·1302	2·083	7·679
Carbonic Acid	1·5290	·12344	1·975	8·101
Oxygen	1·1056	·089253	1·428	11·205
Air	1·0000	·080728	1·29165	12·387
Nitrogen	·9736	·078596	1·258	12·723
Carbonic Oxide	·9674	·0781	1·250	12·804
Olefiant Gas	·9847	·0795	1·272	12·580
Ammoniacal Gas	·5894	·04758	7·613	21·017
Light Carburetted Hydrogen	·5527	·04462	·7139	22·412
Coal Gas	·4381	·03536	·5658	28·279
Hydrogen	·0692	·005592	·0895	178·83

TABLE 87.—WEIGHT AND VOLUME OF BODIES.

(Tod.)

BODIES.	Weight of One Cubic Foot.		Weight of One Cubic Inch.	Cubic Inches in One Pound.
	Oz.	Lb.	Oz.	Cub. In.
METALS.				
Antimony, cast	6,702	418·8750	3·8748	3·8866
Zinc, cast	7,190	449·3750	4·1608	3·8431
Iron, cast	7,207	450·4375	4·1707	3·8364
Tin, cast	7,291	455·6875	4·2193	3·7920
„ hardened	7,299	456·1875	4·2239	3·7878
Pewter	7,471	466·9375	4·3234	3·7007

TABLE 87.—WEIGHT AND VOLUME OF BODIES (*continued*).

BODIES.	Weight of One Cubic Foot.		Weight of One Cubic Inch.	Cubic Inches in One Pound.
	Oz.	Lb.	Oz.	Cub. In.
METALS (*continued*).				
Iron, bar	7,788	486·7500	4·5069	3·5500
Cobalt, cast	7,811	488·1875	4·5202	3·5396
Steel, hard	7,816	488·5000	4·5231	3·5373
„ soft meteoric	7,833	489·5625	4·5329	3·5296
Iron, hammered	7,965	497·8125	4·6093	3·4792
Nickel, cast	8,279	517·4375	4·7910	3·3395
Brass, cast	8,395	524·6875	4·8582	3·2933
„ wire	8,544	534·0000	4·9444	3·2359
Nickel, hammered	8,666	541·6250	5·0150	3·1903
Gun-metal	8,784	549·0000	5·0833	3·1476
Copper, cast	8,788	549·2500	5·0856	3·1461
„ wire	8,878	554·8750	5·1377	3·1140
„ coin	8,915	557·1875	5·1591	3·0959
Bismuth, cast	9,822	613·8750	5·6840	2·8149
Silver, hammered	10,510	656·8750	6·0821	2·6306
„ coin	10,534	658·3750	6·0960	2·6246
„ pure, cast	10,744	671·5000	6·2175	2·5733
Rhodium	11,000	687·5000	6·3657	2·5134
Lead, cast	11,352	709·5000	6·3694	2·4355
Palladium	11,800	737·5000	6·8287	2·5134
Mercury (quicksilver) common	13,568	848·0000	7·8518	2·0377
„ „ pure	14,000	875·0000	8·1018	1·9748
Gold, trinket	15,709	981·8125	9·0908	1·7600
„ coin	17,647	1102·9375	10·2123	1·6124
„ pure, cast	19,258	1203·6250	11·1446	1·4356
„ hammered	19,316	1210·0625	11·2042	1·4280
Platinum, pure	19,500	1218·7500	11·2847	1·4178
„ hammered	20,336	1271·0000	11·7685	1·3595
„ wire	21,041	1315·0625	12·1765	1·3140
„ laminated	22,069	1379·3125	12·7714	1·2528
Iridium, hammered	23,000	1437·5000	13·3101	1·2021
EARTH, STONES, &c.				
Amber	1,078	67·3750	0·62384	25·6474
Coal	1,250	78·7500	0·72337	21·9428
Sand	1,500	93·7500	0·86803	18·4320
Brick	2,000	125·0000	1·15740	13·8240

TABLE 87.—WEIGHT AND VOLUME OF BODIES (*continued*).

BODIES.	Weight of One Cubic Foot.		Weight of One Cubic Inch.	Cubic Inches in One Pound.
	Oz.	Lb.	Oz.	Cub. In.
EARTH, STONES, &c. (*continued*).				
Sulphur, native	2,033	127·0625	1·17650	13·5996
Opal	2,114	132·1250	1·22337	13·0785
Clay	2,160	135·0000	1·25000	12·8000
Gypsum	2,280	142·5000	1·31944	12·1263
Porcelain, Limoges	2,341	146·3125	1·35474	11·8103
„ China	2,385	147·2500	1·38020	11·7351
Stone, paving	2,416	151·4000	1·39814	11·4437
„ common	2,520	157·5000	1·45833	10·9714
Flint	2,594	162·1250	1·50115	10·6584
Spar	2,594	162·1250	1·50115	10·6584
Pebble, English	2,619	163·6875	1·51562	10·5566
Granite, Aberdeen	2,625	164·0625	1·51909	10·5325
Quartz	2,640	165·0000	1·52777	10·4727
Glass, green	2,642	165·1250	1·52893	10·4648
Crystal, rock	2,653	165·8125	1·53530	10·4214
Granite, red Egyptian	2,654	165·8750	1·53587	10·4175
„ Cornish	2,662	166·3750	1·53935	10·3861
Marble, Egyptian	2,668	166·7500	1·54976	10·3628
Slate	2,672	167·0000	1·54629	10·3473
Coral	2,680	167·5000	1·55092	10·3164
Pearl, Oriental	2,684	167·7500	1·55324	10·3010
Glass, bottle	2,733	170·8125	1·58159	10·1163
Marble, green Campanian	2,742	171·3750	1·58735	10·0831
Emerald of Peru	2.775	173·4375	1·60590	9·3632
Chalk, British	2.784	174·0000	1·61111	9·9310
Marble, Parian	2,837	177·3125	1·64178	9·7455
Basalt, Giants' Causeway	2,864	179·0000	1·65740	9·6536
Glass, white	2,892	180·7500	1·67361	9·5601
Limestone	2.950	184·3750	1·70717	9·3721
Asbestos	2.996	187·2500	1·73379	9·2283
Hornblende	3,000	187·5000	1·73611	9·2160
White Lead	3,160	197·5000	1·82870	8·7493
Glass, British flint	3,329	208·0625	1·92650	8·3052
Diamond, average	3,536	221·0000	2·04629	7·8190
Beryl, Oriental	3,549	221·8125	2·05381	7·7903

TABLE 87.—WEIGHT AND VOLUME OF BODIES (*continued*).

BODIES.	Weight of One Cubic Foot.		Weight of One Cubic Inch.	Cubic Inches in One Pound.
	Oz.	Lb.	Oz.	Cub. In.
EARTH, STONES, &c. (*continued*).				
Garnet, common . .	3,576	223·5000	2·06944	7·7315
Topaz, average . .	3,800	237·5000	2·19907	7·2800
Sapphire, Oriental . .	3,994	243·3750	2·25347	7·1001
Garnet, precious . .	4,230	264·3750	2·44791	6·5361
Ruby, Oriental . .	4,283	267·6875	2·47858	6·4590
Jargon of Ceylon .	4,416	276·0000	2·55555	6·2608
Spar, heavy . . .	4,430	276·8750	2·56365	6·2410
Loadstone . . .	4,930	308·1250	2·85300	5·6081
The earth (mean of the globe) . .	5,210	325·6250	3·01504	5·3067
RESINS, GUMS, &c.				
Gunpowder, loose heap	836	52·2500	0·48379	33·0717
Living men . . .	891	55·6875	0·51562	31·0303
Wax	897	56·0625	0·51909	30·8227
Ice	930	58·1250	0·53819	29·7293
Gunp'wder, close shaken	937	58·5625	0·54224	29·5069
Tallow	942	58·8750	0·54513	29·3503
Butter	942	58·8750	0·54513	29·2993
Beeswax	956	59·7500	0·55324	28·9205
Sodium	972	60·7500	0·56250	28·4444
Camphor	989	61·8125	0·56655	27·9555
Rosin	1,100	68·7000	0·63657	25·0909
Pitch	1,150	71·8750	0·66550	24·0417
Opium	1,337	83·5625	0·77372	20·6791
Gum Arabic . . .	1,452	90·7500	0·84027	19·0413
Honey	1,456	91·0000	0·84259	18·9890
Bone, of an ox . .	1,659	103·6875	0·96006	16·6654
„ dry . . .	1,660	103·7500	0·96064	16·6554
Phosphorus	1,714	107·1250	0·99184	16·1307
Alum	1,714	107·1250	0·99184	16·1307
Gunpowder, solid . .	1,745	109·0625	1·00983	15·8441
Nitre (saltpetre) .	1,900	118·7500	1·09953	14·5515
Ivory	1,917	119·8125	1·10937	14·4422
WOODS.				
Cork	240	15·0000	0·13888	115·2000

TABLE 87.—WEIGHT AND VOLUME OF BODIES (*continued*).

BODIES.	Weight of One Cubic Foot.		Weight of One Cubic Inch.	Cubic Inches in One Pound.
	Oz.	Lb.	Oz.	Cub. In.
WOODS (*continued*).				
Poplar	383	23·9375	0·22164	71·7660
Larch	544	34·0000	0·31481	50·8235
Fir, North of England	556	34·7500	0·32175	49·7266
Mahogany, Honduras	560	35·0000	0·32407	49·3714
Cedar, American	561	35·0625	0·32465	49·2833
Poon	579	36·1875	0·33506	47·7512
Willow	585	36·5625	0·35858	47·2615
Cedar	596	37·2500	0·34490	46·3892
Cypress	598	37·3750	0·34664	46·2341
Elm	600	37·5000	0·34722	46·0800
Pitch-pine	660	41·2500	0·38194	41·8909
Pear-tree	661	41·3125	0·38252	41·8275
Walnut	681	42·5625	0·39467	40·5991
Fir, Mar Forest	694	43·3750	0·40162	39·8386
Elder-tree	695	43·4375	0·40219	39·7812
Orange-tree	705	44·0625	0·40798	39·2170
Cherry-tree	715	44·6875	0·41377	38·6685
Teak	745	46·5625	0·43113	37·1114
Fir, Riga	750	46·8750	0·43402	36·8640
Maple	755	47·1857	0·43692	36·6198
Oak, Dantzic	760	47·5000	0·43981	36·3789
Yew, Dutch	788	49·2500	0·45590	35·0862
Apple-tree	793	49·5625	0·45891	34·8656
Yew, Spanish	807	50·4375	0·46701	34·2602
Ash	845	52·8125	0·48900	32·7195
Beech	852	53·2500	0·49305	32·4507
Oak, Canadian	872	54·5000	0·50694	31·7064
Logwood	913	57·0625	0·53125	30·2825
Oak, English	970	60·6250	0·56134	28·5030
Box, French	1,030	64·3750	0·59606	26·8427
Brazil-wood, red	1,031	64·3125	0·59664	26·8680
Mahogany, Spanish	1,063	66·4250	0·61516	26·0143
Oak, English, 60 yrs old	1,170	73·1250	0·67708	23·6307
Ebony, American	1,331	83·1875	0·77025	20·7723
Lignum-vitæ	1,333	83·3125	0·77141	20·7411
LIQUIDS.				
Ether, sulphuric	720	45·0000	0·41666	38·4000

TABLE 87.—WEIGHT AND VOLUME OF BODIES (*continued*).

BODIES.	Weight of One Cubic Foot.		Weight of One Cubic Inch.	Cubic Inches in One Pound.
	Oz.	Lb.	Oz.	Cub. In.
LIQUIDS (*continued*).				
Alcohol, absolute	796	49·7300	0·46064	34·7487
Brandy	837	52·3125	0·48437	33·0322
Bitumen, liquid	848	53·0000	0·49074	32·6037
Turpentine, oil of	870	54·3750	0·50347	31·9632
Ether, muriatic	874	54·6250	0·50578	31·6338
Olive oil	915	57·1875	0·52951	30·2163
Moselle wine	916	57·2500	0·53009	30·1834
Whale oil	923	57·6875	0·53414	29·9544
Proof spirit	930	58·1250	0·53819	29·7290
Linseed oil	940	58·7500	0·54398	29·4127
Castor oil	970	60·6250	0·56134	28·5030
Wine, red port	990	61·8750	0·57291	27·9272
,, of Burgundy	991	61·9375	0·57349	27·8990
,, of Bordeaux	994	62·1250	0·57523	27·8148
,, white Champagne	997	62·3125	0·57696	27·7311
Water, distilled	1,000	62·5000	0·57870	27·6480
Tar	1,015	63·4375	0·58738	27·2396
Vinegar	1,026	64·1250	0·59375	26·9473
Sea-water	1,028	64·2500	0·59490	26·8949
Milk	1,030	64·3750	0·59606	26·8427
Ale (average)	1,035	64·6875	0·59895	26·7130
Blood, human	1,045	65·3125	0·60474	26·4574
Muriatic acid of commerce	1,218	76·1250	0·70486	22·6995
Aqua regia	1,234	77·1250	0·71412	22·4051
Water of Dead Sea	1,240	77·5000	0·71759	22·2580
Nitrous acid	1,452	90·7500	0·84024	19·0082
Nitric acid, or aquafortis	1,500	93·7500	0·86805	18·4000
Boracic acid	1,830	114·3750	1·05902	15·1081
Sulphuric acid	1,848	128·0000	1·06944	13·5000
Quicksilver	(See Metals.)			

TABLE 88.—SPECIFIC GRAVITIES OF BODIES.

(*Adopted by the Standards Department of the Board of Trade.*)

——	Specific Gravity.
Agate	2·6
Aluminium (rolled)	2·67
,, bronze, copper 9, aluminium 1	8·0
Antimony	6·72
Arsenic	5·67
Barium	4·0
Beech	0·8
Bismuth	9·82
Bone	1·8 to 2·0
Boron	2·69
Brass	8·0
Brick, ordinary	2·17
Bromine	2·966
Bronze, copper 86·3, zinc 4·0, tin 9·7	8·45
Bronze, copper 32, zinc 2, tin 5 (Baily's)	8·4
Bronze coins, copper 95, zinc 1, tin 4	8·66
Calcium	1·58
Carbonic acid gas	1·529
Chalk	2·1
Cobalt	7·81
Copper (rolled)	8·94
Cork	0·24
Ebony	1·18
Ether, $C_8H_{10}O_2$	0·73
Glass, ordinary crown	2·45
,, French	2·65
,, flint	3·59
,, crystal	3·33
Glycerine	1·27
Gold	19·32
,, alloy (18 carat)	14·88
,, ,, gold 983, copper 17	18·92
,, ,, 11 ,, 1	17·49
,, ,, 9 ,, 1	17·17
Granite	2·64 to 2·76
Hydrogen	0·06926
Iodine	4·95
Iridium	22·38
Iron :	
,, wrought	7·79

TABLE 88.—SPECIFIC GRAVITIES OF BODIES (*continued*).

———	Specific Gravity.
Iron, cast	7·20
Lead	11·35
Magnesium	1·74
Mahogany	0·56
Manganese	8·01
Marble	2·32 to 2·84
Mercury	13·59593
Nickel (rolled)	8·67
Nitric acid (fuming)	1·451
Nitrogen	0·97137
Oak	0·93
Oil, olive	0·91
„ sperm	0·93
„ colza	0·91
Osmium	21·40
Oxygen	1·10563
Palladium (rolled)	11·78
Palladium alloy, Matthey's Standard, silver 60°/₀, palladium, 40°/₀	11·00
Petroleum	0·84
Pine wood	0·56
Phosphorus	1·77
Porcelain	2·5
Platinum	21·45
„ alloy, platinum 90, iridium 10	21·57
„ „ „ 85, „ 15	21·58
„ „ „ 2, „ 1	21·62
„ „ „ 5, „ 95	22·35
Potassium	0·86
Quartz	2·65122
Rhodium	12·1
Rock crystal, *see* Quartz.	
Ruthenium	12·29
Selenium	4·30
Silver	10·51
„ alloy, silver 37, copper 3	10·38
„ „ 9 „ 1	10·31
„ „ 835 „ 165	10·20
„ „ 80 „ 20	10·06
„ „ 60 „ 40	9·80
„ „ 13¼ „ 2¾	10·17
Slate	2·11
Sodium	0·97

TABLE 88.—SPECIFIC GRAVITIES OF BODIES (*continued*).

	Specific Gravity.
Steel (Whitworth's compressed)	7·796
Strontium	2·54
Sulphur	2·0
Sulphuric acid	1·848
Teak	0·86
Thallium	11·88
Tin	7·29
Water { pure at 0°C. / $D_{4°} = 1$ }	0·9998635
Wax	0·96
Zinc, sheet	7·19

MANUFACTURED METALS.

Tables of Weights of Manufactured Metals.

The following tables are for the most part calculated for the ordinary dimensions manufactured by the trades.

The units of specific gravity and weights adopted in the calculations of these tables, excepting where otherwise stated, are as follows:—

METALS.	Specific Gravity.	Weight of One Cubic Foot.	Weight of One Cubic Inch.
	Water = 1·000.	Pounds.	Pound.
Wrought Iron	7·698	480	·2778
Steel	7·858	490	·2836
Cast Iron	7·217	450	·2604
Lead	11·355	708	·4097
Copper	8·8917	554·4	·3208
Brass (70 copper, 30 zinc)	8·558	533·6	·3088
,, (2 ,, 1 ,,)	8·508	530·5	·3070

The values above given for copper and brass are the results of very careful investigations made by the Broughton Copper Company.

The weights of other metals may be calculated by means of suitable multipliers from the weights of any given metal. Taking the weights of wrought-iron, copper, and the brasses successively as 1, the respective multipliers for the weights of the other metals are as follows :—

METAL.	Wrought Iron = 1.	Copper = 1.	Brass (70 C. and 30 Z.) = 1.
Wrought Iron	1·000	·8658	·8995
Steel	1·0208	·8837	·9182
Cast Iron	·9375	·8117	·8433
Lead	1·4750	1·2771	1·3269
Copper	1·1550	1·0000	1·0388
Brass (70 copper, 30 zinc) .	1·1117	·9625	1·0000
.. (2 .. 1 ..) .	1·1052	·9568	·9941

Bars or Rods, and Wire.

Bars or rods are rolled to dimensions in inches and fractions of an inch, as exhibited in following Tables. Wire generally is rolled to the Imperial Gauge.

Tubes.

Boiler tubes, of iron, steel, or brass, are manufactured to given external diameters. Iron or steel tubes for gas, steam, or water, are manufactured to given internal diameters. Copper tubes also are ordinarily manufactured to internal diameters. The thicknesses of tubes are, for the most part, regulated on the basis of the Imperial Wire-Gauge. But the old Birmingham Wire-Gauge is also, to some extent, followed.

Joists and Girders.

The dimensions, weights, and calculated loads of joists and girders, of iron and steel are given in following Tables. The calculated strengths have been verified by numerous actual tests. The factor of safety, 4, applies to the uniformly loaded joists and girders of Messrs. Measures Brothers & Co. ; the factor, 3. is applied for the distributed loads of the steel joists and girders of Messrs. Dorman, Long & Co. ; and the breaking weight, applied at the centre, is given with the co-efficients of strength in the joists of the Butterley Company.

Joists fail under loads by the breaking of the flange in compression ; never by tensile stress.

The normal length of joists is 30 feet.

TABLE 89.—METALS: WEIGHTS FOR VARIOUS DIMENSIONS.

METAL.	Specific Weight.	Weight of One Cubic Foot.	Weight of One Square Foot.			Weight of One Lineal Ft. 1 In. Sq.	Weight of One Cubic Inch.
			1 Inch Thick.	⅛th Inch Thick.	1/10th Inch Thick.		
	Wro'ght Iron = 1.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.
Aluminium, wrought	·348	167	13·92	1·74	1·39	1·160	·097
,, cast . .	·333	160	13·33	1·67	1·33	1·111	·092
Antimony . .	·879	418	34·83	4·35	3·48	2·902	·242
Bismuth . . .	1·285	617	51·42	6·42	5·14	4·283	·357
Brass, cast . .	1·052	505	42·08	5·26	4·21	3·507	·292
,, sheet . .	1·098	527	43·92	5·49	4·39	3·652	·304
,, yellow . .	1·079	518	43·17	5·40	4·32	3·597	·298
,, Muntz metal.	1·062	511	42·58	5·32	4·26	3·549	·296
,, wire . .	1·110	533	44·42	5·55	4·44	3·701	·308
Bronze, gun-metal .	1·106	531	44·25	5·54	4·43	3·688	·307
,, mill bearings .	1·133	544	45·33	5·66	4·53	3·780	·315
,, small bells .	1·004	482	40·17	5·04	4·02	3·347	·279
,, speculum metal	·969	465	38·75	4·84	3·88	3·299	·269
Copper, sheet . .	1·114	549	45·75	5·72	4·58	3·813	·318
,, hammered .	1·158	556	46·33	5·79	4·63	3·861	·322
,, wire . .	1·154	554	46·17	5·77	4·62	3·778	·315
Gold . . .	2·500	1200	100·00	12·50	10·00	8·333	·694
Iron, cast . . .	·937	450	37·50	4·69	3·75	3·125	·260
,, wrought . .	1·000	480	40·00	5·00	4·00	3·333	·278
Lead, sheet . .	1·488	712	59·33	7·41	5·93	4·944	·412
Manganese . .	1·040	499	41·58	5·20	4·16	3·465	·289
Mercury . . .	1·769	849	70·75	8·84	7·07	5·896	·491
Nickel, hammered .	1·127	541	45·08	5·64	4·51	3·757	·313
,, cast . .	1·075	516	43·00	5·37	4·30	3·583	·299
Platinum . .	2·796	1342	111·83	13·97	11·18	9·320	·777
Silver . . .	1·365	655	54·58	6·82	5·46	4·549	·379
Steel . . .	1·020	490	40·83	5·12	4·10	3·403	·284
Tin	·962	462	38·50	4·81	3·85	3·208	·268
Zinc, sheet . .	·935	449	37·42	4·67	3·74	3·118	·260
,, cast . . .	·892	428	35·67	4·46	3·57	2·972	·248

TABLE 90.—WEIGHTS OF FLAT BAR IRON.

Length 1 Foot.

Thickness.	Width in Inches.								
	1/2	5/8	3/4	7/8	1	1 1/8	1 1/4	1 3/8	1 1/2
Inch.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
1/8	·208	·260	·312	·365	·417	·469	·521	·573	·625
3/16	·312	·391	·469	·547	·625	·703	·781	·859	·937
1/4	·417	·521	·625	·729	·833	·938	1·04	1·15	1·25
5/16	·521	·651	·781	·911	1·04	1·17	1·30	1·43	1·56
3/8	·625	·781	·937	1·09	1·25	1·41	1·56	1·72	1·88
7/16	·729	·911	1·09	1·28	1·46	1·64	1·82	2·01	2·19
1/2	·833	1·04	1·25	1·46	1·67	1·88	2·08	2·29	2·50
9/16	·937	1·17	1·41	1·64	1·88	2·11	2·34	2·58	2·81
5/8	1·04	1·30	1·56	1·82	2·08	2·34	2·60	2·86	3·13
11/16	1·15	1·43	1·72	2·01	2·29	2·58	2·86	3·15	3·44
3/4	1·25	1·56	1·87	2·19	2·50	2·81	3·13	3·44	3·75
13/16	1·35	1·69	2·03	2·37	2·71	3·05	3·39	3·72	4·06
7/8	1·46	1·82	2·19	2·55	2·92	3·28	3·65	4·01	4·38
15/16	1·56	1·95	2·34	2·73	3·13	3·52	3·91	4·30	4·69
1	1·67	2·08	2·50	2·92	3·33	3·75	4·17	4·58	5·00

Thickness.	Width in Inches.									
	1 5/8	1 3/4	1 7/8	2	2 1/8	2 1/4	2 3/8	2 1/2	2 5/8	2 3/4
Inch.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
1/8	·677	·729	·781	·833	...	...	...	...	...	...
3/16	1·02	1·09	1·17	1·25	1·33	1·41	1·48	1·56	1·64	1·72
1/4	1·35	1·46	1·56	1·67	1·77	1·88	1·98	2·08	2·19	2·29
5/16	1·69	1·82	1·95	2·08	2·21	2·34	2·47	2·60	2·73	2·86
3/8	2·03	2·19	2·34	2·50	2·66	2·81	2·97	3·13	3·28	3·44
7/16	2·37	2·55	2·73	2·92	3·10	3·28	3·46	3·65	3·83	4·01
1/2	2·71	2·92	3·13	3·33	3·54	3·75	3·96	4·17	4·38	4·58
9/16	3·05	3·28	3·52	3·75	3·98	4·22	4·45	4·69	4·92	5·16
5/8	3·39	3·65	3·91	4·17	4·43	4·69	4·95	5·21	5·47	5·73
11/16	3·72	4·01	4·30	4·58	4·87	5·16	5·44	5·73	6·02	6·30
3/4	4·06	4·38	4·69	5·00	5·31	5·63	5·94	6·25	6·56	6·88
13/16	4·40	4·74	5·08	5·42	5·76	6·09	6·43	6·77	7·11	7·45
7/8	4·74	5·10	5·47	5·83	6·20	6·56	6·93	7·29	7·66	8·02
15/16	5·08	5·47	5·86	6·25	6·64	7·03	7·42	7·81	8·20	8·59
1	5·42	5·83	6·25	6·67	7·08	7·50	7·92	8·33	8·75	9·17

TABLE 90.—WEIGHTS OF FLAT BAR IRON (*continued*).

Thickness.	Width in Inches.									
	$2\frac{7}{8}$	3	$3\frac{1}{4}$	$3\frac{1}{2}$	$3\frac{3}{4}$	4	$4\frac{1}{4}$	$4\frac{1}{2}$	$4\frac{3}{4}$	5
Inch.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
$\frac{3}{16}$	1·80	1·88	2·03	...	...	...	...	...	...	...
$\frac{1}{4}$	2·40	2·50	2·71	2·92	3·13	3·33	3·54	3·75	3·96	4·17
$\frac{5}{16}$	3·00	3·13	3·39	3·65	3·91	4·17	4·43	4·69	4·95	5·21
$\frac{3}{8}$	3·59	3·75	4·06	4·38	4·69	5·00	5·31	5·63	5·94	6·25
$\frac{7}{16}$	4·19	4·38	4·74	5·10	5·47	5·83	6·20	6·56	6·93	7·29
$\frac{1}{2}$	4·79	5·00	5·42	5·83	6·25	6·67	7·08	7·50	7·92	8·33
$\frac{9}{16}$	5·39	5·63	6·09	6·56	7·03	7·50	7·97	8·44	8·91	9·38
$\frac{5}{8}$	6·00	6·25	6·77	7·29	7·81	8·33	8·85	9·38	9·90	10·4
$\frac{11}{16}$	6·59	6·88	7·45	8·02	8·59	9·17	9·74	10·3	10·9	11·5
$\frac{3}{4}$	7·19	7·50	8·13	8·75	9·38	10·0	10·6	11·3	11·9	12·5
$\frac{13}{16}$	7·79	8·13	8·80	9·48	10·2	10·8	11·5	12·2	12·9	13·5
$\frac{7}{8}$	8·39	8·75	9·48	10·2	10·9	11·7	12·4	13·1	13·9	14·6
$\frac{15}{16}$	8·98	9·38	10·2	10·9	11·7	12·5	13·3	14·1	14·8	15·6
1	9·58	10·0	10·8	11·7	12·5	13·3	14·2	15·0	15·8	16·7

Thickness.	Width in Inches.								
	$5\frac{1}{2}$	6	$6\frac{1}{2}$	7	8	9	10	11	12
Inch.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
$\frac{1}{4}$	4·58	5·00	5·42	5·83	6·67	7·50	8·33	9·17	10·0
$\frac{5}{16}$	5·73	6·25	6·77	7·29	8·33	9·38	10·4	11·5	12·5
$\frac{3}{8}$	6·88	7·50	8·13	8·75	10·0	11·3	12·5	13·8	15·0
$\frac{7}{16}$	8·02	8·75	9·47	10·2	11·7	13·1	14·6	16·0	17·5
$\frac{1}{2}$	9·17	10·0	10·8	11·7	13·3	15·0	16·7	18·3	20·0
$\frac{9}{16}$	10·3	11·3	12·2	13·1	15·0	16·9	18·8	20·6	22·5
$\frac{5}{8}$	11·5	12·5	13·5	14·6	16·7	18·8	20·8	22·9	25·0
$\frac{11}{16}$	12·6	13·8	14·9	16·0	18·3	20·6	22·9	25·2	27·5
$\frac{3}{4}$	13·8	15·0	16·3	17·5	20·0	22·5	25·0	27·5	30·0
$\frac{13}{16}$	14·9	16·3	17·6	19·0	21·7	24·4	27·1	29·8	32·5
$\frac{7}{8}$	16·0	17·5	19·0	20·4	23·3	26·3	29·2	32·1	35·0
$\frac{15}{16}$	17·2	18·8	20·3	21·9	25·0	28·1	31·3	34·4	37·5
1	18·3	20·0	21·7	23·3	26·7	30·0	33·3	36·7	40·0

TABLE 91.—WEIGHTS OF ROUND IRON.

Length, 1 Foot.

Diam.	Weight.	Diam.	Weight.	Diam.	Weight.	Diam.	Weight.
Inches.	Lbs.	Inches.	Lbs.	Inches.	Lbs.	Inches.	Cwts.
$\frac{1}{8}$	·041	1	2·62	$2\frac{3}{8}$	14·8	8	1·496
$\frac{5}{32}$	·064	$1\frac{1}{32}$	2·78	$2\frac{7}{16}$	15·6	$8\frac{1}{2}$	1·689
$\frac{3}{16}$	·092	$1\frac{1}{16}$	2·96	$2\frac{1}{2}$	16·4	9	1·893
$\frac{7}{32}$	·125	$1\frac{3}{32}$	3·14	$2\frac{5}{8}$	18·0	$9\frac{1}{2}$	2·110
$\frac{1}{4}$	·164	$1\frac{1}{8}$	3·31	$2\frac{3}{4}$	19·8	10	2·338
$\frac{9}{32}$	·207	$1\frac{5}{32}$	3·50	$2\frac{7}{8}$	21·6	$10\frac{1}{2}$	2·577
$\frac{5}{16}$	·256	$1\frac{3}{16}$	3·69	3	23·6	11	2·828
$\frac{11}{32}$	·310	$1\frac{7}{32}$	3·90	$3\frac{1}{8}$	25·6	$11\frac{1}{2}$	3·088
$\frac{3}{8}$	·368	$1\frac{1}{4}$	4·09	$3\frac{1}{4}$	27·7	12	3·366
$\frac{13}{32}$	·432	$1\frac{9}{32}$	4·29	$3\frac{3}{8}$	29·8	$12\frac{1}{2}$	3·656
$\frac{7}{16}$	·501	$1\frac{5}{16}$	4·51	$3\frac{1}{2}$	32·1	13	3·950
$\frac{15}{32}$	·575	$1\frac{11}{32}$	4·70	$3\frac{5}{8}$	34·4	$13\frac{1}{2}$	4·260
$\frac{1}{2}$	·654	$1\frac{3}{8}$	4·95	$3\frac{3}{4}$	36·8	14	4·581
$\frac{17}{32}$	·740	$1\frac{7}{16}$	5·08	$3\frac{7}{8}$	39·3	$14\frac{1}{2}$	4·915
$\frac{9}{16}$	·828	$1\frac{1}{2}$	5·89	4	41·9	15	5·259
$\frac{19}{32}$	·922	$1\frac{9}{16}$	6·29	$4\frac{1}{4}$	47·3	$15\frac{1}{2}$	5·616
$\frac{5}{8}$	1·02	$1\frac{5}{8}$	6·91	$4\frac{1}{2}$	53·0	16	5·984
$\frac{21}{32}$	1·13	$1\frac{11}{16}$	7·46	$4\frac{3}{4}$	59·1	$16\frac{1}{2}$	6·364
$\frac{11}{16}$	1·24	$1\frac{3}{4}$	8·02	5	65·5	17	6·755
$\frac{23}{32}$	1·27	$1\frac{13}{16}$	8·60	$5\frac{1}{4}$	72·2	$17\frac{1}{2}$	7·159
$\frac{3}{4}$	1·47	$1\frac{7}{8}$	9·20	$5\frac{1}{2}$	79·2	18	7·573
$\frac{25}{32}$	1·60	$1\frac{15}{16}$	9·83	$5\frac{3}{4}$	86·6	19	8·438
$\frac{13}{16}$	1·73	2	10·5	6	94·2	20	9·350
$\frac{27}{32}$	1·86	$2\frac{2}{16}$	11·1			21	10·31
$\frac{7}{8}$	2·00	$2\frac{1}{8}$	11·8	Inches.	Cwts.	22	11·31
$\frac{29}{32}$	2·15	$2\frac{1}{16}$	12·6	$6\frac{1}{2}$	·9876	23	12·37
$\frac{15}{16}$	2·30	$2\frac{1}{4}$	13·3	7	1·145	24	13·46
$\frac{31}{32}$	2·46	$2\frac{5}{16}$	14·0	$7\frac{1}{2}$	1·315		

TABLE 92.—WEIGHTS OF SQUARE IRON.

Length, 1 Foot.

Side of Square.	Weight.	Side of Square.	Weight.	Side of Square.	Weight.	Side of Square.	Weight.
Inches.	Lbs.	Inches.	Lbs.	Inches.	Lbs.	Inches.	Lbs.
1/8	·052	11/16	1·58	1 7/32	4·96	2 1/2	20·8
5/32	·081	23/32	1·72	1 1/4	5·21	2 5/8	23·0
3/16	·117	3/4	1·88	1 5/16	5·74	2 3/4	25·2
7/32	·159	25/32	2·03	1 3/8	6·30	2 7/8	27·6
1/4	·208	13/16	2·20	1 7/16	6·89	3	30·0
9/32	·265	27/32	2·40	1 1/2	7·50	3 1/4	35·2
5/16	·326	7/8	2·55	1 9/16	8·14	3 1/2	40·8
11/32	·395	29/32	2·75	1 5/8	8·80	3 3/4	46·9
3/8	·469	15/16	2·93	1 11/16	9·60	4	53·3
13/32	·550	31/32	3·12	1 3/4	10·2	4 1/4	60·2
7/16	·638	1	3·33	1 13/16	11·0	4 1/2	67·5
15/32	·732	1 1/32	3·54	1 7/8	11·7	4 3/4	75·2
1/2	·833	1 1/16	3·76	1 15/16	12·5	5	83·3
17/32	·940	1 3/32	4·03	2	13·3	5 1/4	91·9
9/16	1·06	1 1/8	4·22	2 1/8	15·1	5 1/2	100·8
19/32	1·17	1 5/32	4·48	2 1/4	16·9	5 3/4	110·2
5/8	1·30	1 3/16	4·70	2 3/8	18·8	6	120·0
21/32	1·43						

French Bar Iron.

The length of bars varies. In general, it is 4 metres for the larger bars, and 6 metres for the smaller bars; with a tolerance of ½ metre, more or less. Square iron advances in size by 1 millimetre from 6 to 86 millimetres. Round iron advances by 1 millimetre from 6 to 28 millimetres; and by 2 millimetres from 28 to 130 millimetres, with a few exceptions. Flat bar iron:—

16, 18, 20, 22, 24, 26, 28, 30, 32, 34, 36 millimetres, by 1 to 3 millimetres thick.

18, 20, 22, 24, 26, 28, 30, 32 millimetres, by 4 to 14 millimetres thick.

34, 40, 42, 46, 48 millimetres, by 1½ to 30 millimetres thick.

48, 50, 52, 54, 58, 60, 62, 64, 66, 68, 70, 72 millimetres, by 2 to 40 millimetres thick.

75 by 2 to 40, 80 by 2 to 45, 85 by 2 to 50, 90 by 2 to 45, 95 by 2 to 50, 100 by 2 to 50, 110 by 2 to 40, 115 by 2 to 40,

135 by 3 to 45, 140 by 3 to 40, 150 by 3 to 45, 160 by 3 to 45, 165 by 3 to 45, 180 by 3 to 45, 210 by 8 to 45, 250 by 7 to 40, 300 by 8 to 40, 355 by 8 to 40, 400 by 8 to 40, 450 by 8 to 40 millimetres thick.

TABLE 93.—WROUGHT IRON: WEIGHT OF ONE SQUARE FOOT FOR ALL THICKNESSES OF THE IMPERIAL WIRE GAUGE (Standards Department).

Specific Gravity, 7·80.

I. W. G. Gauge Number.	Thickness.	Weight per Square Foot.	I. W. G. Gauge Number.	Thickness.	Weight per Square Foot.
No.	Inch.	Pounds.	No.	Inch.	Pounds.
7/0	·500	20·254	23	·024	·972
6/0	·464	18·796	24	·022	·891
5/0	·432	17·500	25	·020	·810
4/0	·400	16·203	26	·018	·729
3/0	·372	15·069	27	·0164	·664
2/0	·348	14·097	28	·0148	·600
0	·324	13·125	29	·0136	·551
1	·300	12·153	30	·0124	·502
2	·276	11·180	31	·0116	·470
3	·252	10·208	32	·0108	·437
4	·232	9·398	33	·0100	·405
5	·212	8·588	34	·0092	·373
6	·192	7·778	35	·0084	·340
7	·176	7·130	36	·0076	·308
8	·160	6·481	37	·0068	·275
9	·144	5·833	38	·0060	·243
10	·128	5·185	39	·0052	·211
11	·116	4·699	40	·0048	·194
12	·104	4·213	41	·0044	·178
13	·092	3·727	42	·0040	·162
14	·080	3·241	43	·0036	·146
15	·072	2·917	44	·0032	·130
16	·064	2·593	45	·0028	·113
17	·056	2·268	46	·0024	·097
18	·048	1·944	47	·0020	·081
19	·040	1·620	48	·0016	·065
20	·036	1·458	49	·0012	·049
21	·032	1·296	50	·0010	·041
22	·028	1·134			

TABLE 94.—ANGLE IRONS AND TEE IRONS: WEIGHT.

Length, 1 Foot.

Average Thickness.	Sum of the Width and Depth in Inches.							
	2	2¼	2½	2¾	3	3¼	3½	3¾
Inch.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
1/8	·78	·88	·99	1·09	1·20	1·30	1·41	1·51
3/16	1·13	1·29	1·45	1·60	1·76	1·91	2·07	2·23
1/4	1·46	1·67	1·88	2·08	2·29	2·50	2·71	2·92
5/16	1·76	2·02	2·28	2·54	2·80	3·06	3·32	3·58
3/8	...	...	...	...	3·28	3·59	3·91	4·22
7/16	...	...	...	...	...	...	4·48	4·84

Average Thickness.	Sum of the Width and Depth in Inches.							
	4	4¼	4½	4¾	5	5¼	5½	5¾
Inch.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
3/16	2·38	2·54	2·70	2·85	3·01	3·16	3·32	3·48
1/4	3·13	3·33	3·54	3·75	3·96	4·17	4·38	4·58
5/16	3·84	4·10	4·36	4·62	4·88	5·14	5·40	5·66
3/8	4·53	4·84	5·16	5·47	5·78	6·09	6·41	6·72
7/16	5·20	5·56	5·92	6·29	6·65	7·02	7·38	7·75
1/2	...	...	6·67	7·08	7·50	7·92	8·33	8·75
9/16	...	...	7·38	7·85	8·32	8·79	9·26	9·73
5/8	...	...	...	8·59	9·11	9·63	10·16	10·68
11/16	...	...	...	...	10·03	10·62	11·20	11·78
3/4	...	...	...	...	...	...	...	12·50

Average Thickness.	Sum of the Width and Depth in Inches.							
	6	6½	7	7½	8	8½	9	9½
Inch.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
1/4	4·79	5·21	5·63	6·04	6·46	6·88	7·29	7·71
5/16	5·92	6·45	6·97	7·49	8·01	8·53	9·05	9·57
3/8	7·03	7·66	8·28	8·91	9·53	10·16	10·78	11·41
7/16	8·11	8·84	9·57	10·30	11·03	11·76	12·49	13·22
1/2	9·17	10·00	10·83	11·67	12·50	13·33	14·17	15·00
9/16	10·20	11·13	12·07	13·01	13·94	14·88	15·82	16·76
5/8	11·19	12·24	13·28	14·32	15·36	16·41	17·45	18·49
11/16	12·37	13·54	14·70	15·87	17·03	18·20	19·36	20·53
3/4	13·13	14·38	15·63	16·88	18·13	19·38	20·63	21·88
7/8	14·95	16·41	17·86	19·32	20·78	22·24	23·70	25·16
1	...	...	...	21·67	23·33	25·00	26·67	28·33

TABLE 94.—ANGLE IRONS AND TEE IRONS: WEIGHT (*continued*).

Average Thickness.	Sum of the Width and Depth in Inches.							
	10	10½	11	12	13	14	15	16
Inch.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
3/8	12·03	12·66	13·28	14·53	...	...	...	...
7/16	13·95	14·67	15·40	16·86	18·31	19·77	21·22	22·67
1/2	15·83	16·67	17·50	19·17	20·84	22·50	24·17	25·84
9/16	17·70	18·63	19·57	21·44	23·31	25·19	27·06	28·93
5/8	19·53	20·57	21·61	23·70	25·78	27·87	29·95	32·03
11/16	21·69	22·86	24·03	26·36	28·70	31·03	33·36	35·70
3/4	23·13	24·38	25·63	28·13	30·63	33·13	35·63	38·13
7/8	26·61	28·07	29·53	32·45	35·36	38·28	41·19	44·12
1	30·00	31·67	33·333	36·67	40·00	43·30	46 67	50·00

TABLE 95.—WEIGHT OF FLAT BAR STEEL.

Length, 1 Foot.

Thickness.	Width.								
	1/2	5/8	3/4	7/8	1	1 1/8	1 1/4	1 3/8	1 1/2
Inch.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
1/8	·213	·266	·319	·372	·425	·478	·532	·584	·638
3/16	·320	·399	·478	·558	·638	·717	·797	·877	·957
1/4	·425	·532	·638	·744	·851	·960	1·06	1·17	1·28
5/16	·532	·665	·797	·930	1·06	1·20	1·33	1·46	1·59
3/8	·638	·797	·957	1·11	1·28	1·43	1·59	1·75	1·91
7/16	·744	·930	1·12	1·30	1·49	1·67	1·86	2·05	2·23
1/2	·851	1·06	1·28	1·49	1·70	1·91	2·13	2·34	2·55
9/16	·957	1·20	1·43	1·67	1·91	2·15	2·39	2·63	2·87
5/8	1·06	1·33	1·59	1·86	2·13	2·39	2·66	2·92	3·19
11/16	1·17	1·46	1·75	2·05	2·34	2·63	2·92	3·21	3·51
3/4	1·28	1·59	1·91	2·23	2·55	2·87	3·19	3·51	3·83
13/16	1·38	1·73	2·07	2·42	2·76	3·11	3·45	3·70	4·15
7/8	1·49	1·86	2·23	2·60	2·98	3·35	3·72	4·09	4·47
15/16	1·59	1·99	2·39	2·79	3·19	3·59	3·99	4·39	4·78
1	1·70	2·13	2·55	2·98	3·40	3·83	4·25	4·68	5·10

TABLE 95.—WEIGHT OF FLAT BAR STEEL (*continued*).

Thickness.	Width.									
	$1\frac{5}{8}$	$1\frac{3}{4}$	$1\frac{7}{8}$	2	$2\frac{1}{8}$	$2\frac{1}{4}$	$2\frac{3}{8}$	$2\frac{1}{2}$	$2\frac{5}{8}$	$2\frac{3}{4}$
Inch.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
$\frac{1}{8}$	·691	·744	·797	·851	·904	·958	1·01	1·06	1·11	1·16
$\frac{3}{16}$	1·04	1·11	1·196	1·28	1·36	1·43	1·51	1·59	1·67	1·75
$\frac{1}{4}$	1·38	1·49	1·59	1·70	1·81	1·91	2·02	2·13	2·23	2·34
$\frac{5}{16}$	1·73	1·86	1·99	2·13	2·26	2·39	2·52	2·66	2·79	2·92
$\frac{3}{8}$	2·07	2·23	2·39	2·55	2·71	2·87	3·03	3·19	3·35	3·51
$\frac{7}{16}$	2·42	2·60	2·79	2·98	3·16	3·35	3·53	3·72	3·91	4·09
$\frac{1}{2}$	2·76	2·98	3·19	3·40	3·61	3·83	4·01	4·25	4·46	4·68
$\frac{9}{16}$	3·11	3·35	3·59	3·83	4·07	4·31	4·54	4·78	5·02	5·26
$\frac{5}{8}$	3·45	3·72	3·99	4·25	4·52	4·78	5·05	5·31	5·58	5·84
$\frac{11}{16}$	3·80	4·09	4·39	4·68	4·97	5·26	5·56	5·86	6·14	6·43
$\frac{3}{4}$	4·14	4·46	4·78	5·10	5·42	5·74	6·06	6·38	6·69	7·01
$\frac{13}{16}$	4·49	4·84	5·18	5·53	5·87	6·22	6·57	6·92	7·26	7·60
$\frac{7}{8}$	4·83	5·21	5·58	5·96	6·32	6·79	7·07	7·44	7·81	8·18
$\frac{15}{16}$	5·18	5·58	5·98	6·38	6·78	7·18	7·58	7·98	8·37	8·77
1	5·53	5·96	6·38	6·81	7·23	7·66	8·08	8·51	8·93	9·36

Thickness.	Width.									
	$2\frac{7}{8}$	3	$3\frac{1}{4}$	$3\frac{1}{2}$	$3\frac{3}{4}$	4	$4\frac{1}{4}$	$4\frac{1}{2}$	$4\frac{3}{4}$	5
Inch.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
$\frac{1}{8}$	1·22	1·28	1·38	1·49	1·59	1·70	...	...	...	...
$\frac{3}{16}$	1·83	1·91	2·07	2·23	2·39	2·55	...	...	...	...
$\frac{1}{4}$	2·44	2·55	2·76	2·98	3·19	3·40	3·61	3·83	4·04	4·25
$\frac{5}{16}$	3·06	3·19	3·45	3·72	3·98	4·25	4·51	4·78	5·05	5·32
$\frac{3}{8}$	3·67	3·83	4·14	4·46	4·78	5·10	5·44	5·74	6·06	6·38
$\frac{7}{16}$	4·28	4·46	4·83	5·21	5·58	5·95	6·32	6·70	7·07	7·44
$\frac{1}{2}$	4·89	5·10	5·53	5·95	6·38	6·80	7·23	7·66	8·08	8·50
$\frac{9}{16}$	5·50	5·74	6·22	6·70	7·18	7·66	8·13	8·61	9·09	9·57
$\frac{5}{8}$	6·11	6·38	6·91	7·44	7·97	8·50	9·04	9·57	10·10	10·63
$\frac{11}{16}$	6·72	7·02	7·60	8·19	8·78	9·36	9·94	10·52	11·11	11·70
$\frac{3}{4}$	7·33	7·65	8·29	8·93	9·56	10·20	10·85	11·48	12·12	12·76
$\frac{13}{16}$	7·95	8·29	8·98	9·68	10·37	11·06	11·75	12·44	13·13	13·82
$\frac{7}{8}$	8·55	8·93	9·67	10·41	11·16	11·90	12·65	13·40	14·14	14·89
$\frac{15}{16}$	9·17	9·57	10·37	11·16	11·96	12·76	13·56	14·35	15·15	15·95
1	9·78	10·21	11·06	11·91	12·76	13·68	14·46	15·31	16·16	17·01

TABLE 94.—ANGLE IRONS AND TEE IRONS: WEI (*continued*).

Average Thickness.	Sum of the Width and Depth in Inches.						
	10	$10\frac{1}{2}$	11	12	13	14	15
Inch.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
$\frac{3}{8}$	12·03	12·66	13·28	14·53	...	...	...
$\frac{7}{16}$	13·95	14·67	15·40	16·86	18·31	19·77	21·22
$\frac{1}{2}$	15·83	16·67	17·50	19·17	20·84	22·50	24·17
$\frac{9}{16}$	17·70	18·63	19·57	21·44	23·31	25·19	27·06
$\frac{5}{8}$	19·53	20·57	21·61	23·70	25·78	27·87	29·95
$\frac{11}{16}$	21·69	22·86	24·03	26·36	28·70	31·03	33·36
$\frac{3}{4}$	23·13	24·38	25·63	28·13	30·63	33·13	35·63
$\frac{7}{8}$	26·61	28·07	29·53	32·45	35·36	38·28	41·19
1	30·00	31·67	33·333	36·67	40·00	43·30	46 67

TABLE 95.—WEIGHT OF FLAT BAR STEEL.

Length, 1 Foot.

Thickness.	Width.							
	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1	$1\frac{1}{8}$	$1\frac{1}{4}$	$1\frac{3}{8}$
Inch.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
$\frac{1}{8}$	·213	·266	·319	·372	·425	·478	·532	·58
$\frac{3}{16}$	·320	·399	·478	·558	·638	·717	·797	·87
$\frac{1}{4}$	·425	·532	·638	·744	·851	·960	1·06	1·17
$\frac{5}{16}$	·532	·665	·797	·930	1·06	1·20	1·33	1·46
$\frac{3}{8}$	·638	·797	·957	1·11	1·28	1·43	1·59	1·75
$\frac{7}{16}$	·744	·930	1·12	1·30	1·49	1·67	1·86	2·05
$\frac{1}{2}$	·851	1·06	1·28	1·49	1·70	1·91	2·13	2·34
$\frac{9}{16}$	·957	1·20	1·43	1·67	1·91	2·15	2·39	2·63
$\frac{5}{8}$	1·06	1·33	1·59	1·86	2·13	2·39	2·66	2·92
$\frac{11}{16}$	1·17	1·46	1·75	2·05	2·34	2·63	2·92	3·21
$\frac{3}{4}$	1·28	1·59	1·91	2·23	2·55	2·87	3·19	3·51
$\frac{13}{16}$	1·38	1·73	2·07	2·42	2·76	3·11	3·45	3·70
$\frac{7}{8}$	1·49	1·86	2·23	2·60	2·98	3·35	3·72	4·09
$\frac{15}{16}$	1·59	1·99	2·39	2·79	3·19	3·59	3·99	4·39
1	1·70	2·13	2·55	2·98	3·40	3·83	4·25	4·68

STEEL.

Diam.	Weig
Inches.	Cwt
8	1·52
8 ½	1·72
9	1·93
9 ½	2·1
10	2·3
10 ½	2·6
11	2·8
11 ½	3·1
12	3·4
12 ½	3·7
13	4·0
13 ½	4·3
14	4·6
14 ½	5·3
[illegible]	5·6
[illegible] ½	5·7
[illegible]	6·1
[illegible] ½	6·49
[illegible]	6·89
[illegible]	7·30
[illegible]	7·73
[illegible]	8·61
[illegible]	9·54
[illegible]	10·53
[illegible]	11·55
[illegible]	12·63
[illegible]	13·74

TABLE 94.—ANGLE IRONS AND TEE IRONS: WEIGHT (*continued*).

Average Thickness.	Sum of the Width and Depth in Inches.							
	10	$10\frac{1}{2}$	11	12	13	14	15	16
Inch.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
$\frac{3}{8}$	12·03	12·66	13·28	14·53	...	...	...	...
$\frac{7}{16}$	13·95	14·67	15·40	16·86	18·31	19·77	21·22	22·67
$\frac{1}{2}$	15·83	16·67	17·50	19·17	20·84	22·50	24·17	25·84
$\frac{9}{16}$	17·70	18·63	19·57	21·44	23·31	25·19	27·06	28·93
$\frac{5}{8}$	19·53	20·57	21·61	23·70	25·78	27·87	29·95	32·03
$\frac{11}{16}$	21·69	22·86	24·03	26·36	28·70	31·03	33·36	35·70
$\frac{3}{4}$	23·13	24·38	25·63	28·13	30·63	33·13	35·63	38·13
$\frac{7}{8}$	26·61	28·07	29·53	32·45	35·36	38·28	41·19	44·12
1	30·00	31·67	33·333	36·67	40·00	43·30	46 67	50·00

TABLE 95.—WEIGHT OF FLAT BAR STEEL.

Length, 1 Foot.

Thickness.	Width.								
	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1	$1\frac{1}{8}$	$1\frac{1}{4}$	$1\frac{3}{8}$	$1\frac{1}{2}$
Inch.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
$\frac{1}{8}$	·213	·266	·319	·372	·425	·478	·532	·584	·638
$\frac{3}{16}$	·320	·399	·478	·558	·638	·717	·797	·877	·957
$\frac{1}{4}$	·425	·532	·638	·744	·851	·960	1·06	1·17	1·28
$\frac{5}{16}$	·532	·665	·797	·930	1·06	1·20	1·33	1·46	1·59
$\frac{3}{8}$	·638	·797	·957	1·11	1·28	1·43	1·59	1·75	1·91
$\frac{7}{16}$	·744	·930	1·12	1·30	1·49	1·67	1·86	2·05	2·23
$\frac{1}{2}$	·851	1·06	1·28	1·49	1·70	1·91	2·13	2·34	2·55
$\frac{9}{16}$	·957	1·20	1·43	1·67	1·91	2·15	2·39	2·63	2·87
$\frac{5}{8}$	1·06	1·33	1·59	1·86	2·13	2·39	2·66	2·92	3·19
$\frac{11}{16}$	1·17	1·46	1·75	2·05	2·34	2·63	2·92	3·21	3·51
$\frac{3}{4}$	1·28	1·59	1·91	2·23	2·55	2·87	3·19	3·51	3·83
$\frac{13}{16}$	1·38	1·73	2·07	2·42	2·76	3·11	3·45	3·70	4·15
$\frac{7}{8}$	1·49	1·86	2·23	2·60	2·98	3·35	3·72	4·09	4·47
$\frac{15}{16}$	1·59	1·99	2·39	2·79	3·19	3·59	3·99	4·39	4·78
1	1·70	2·13	2·55	2·98	3·40	3·83	4·25	4·68	5·10

TABLE 95.—WEIGHT OF FLAT BAR STEEL (*continued*).

Thickness.	Width.									
	1 5/8	1 3/4	1 7/8	2	2 1/8	2 1/4	2 3/8	2 1/2	2 5/8	2 3/4
Inch.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
1/8	·691	·744	·797	·851	·904	·958	1·01	1·06	1·11	1·16
3/16	1·04	1·11	1·196	1·28	1·36	1·43	1·51	1·59	1·67	1·75
1/4	1·38	1·49	1·59	1·70	1·81	1·91	2·02	2·13	2·23	2·34
5/16	1·73	1·86	1·99	2·13	2·26	2·39	2·52	2·66	2·79	2·92
3/8	2·07	2·23	2·39	2·55	2·71	2·87	3·03	3·19	3·35	3·51
7/16	2·42	2·60	2·79	2·98	3·16	3·35	3·53	3·72	3·91	4·09
1/2	2·76	2·98	3·19	3·40	3·61	3·83	4·04	4·25	4·46	4·68
9/16	3·11	3·35	3·59	3·83	4·07	4·31	4·54	4·78	5·02	5·26
5/8	3·45	3·72	3·99	4·25	4·52	4·78	5·05	5·31	5·58	5·84
11/16	3·80	4·09	4·39	4·68	4·97	5·26	5·56	5·86	6·14	6·43
3/4	4·14	4·46	4·78	5·10	5·42	5·74	6·06	6·38	6·69	7·01
13/16	4·49	4·84	5·18	5·53	5·87	6·22	6·57	6·92	7·26	7·60
7/8	4·83	5·21	5·58	5·96	6·32	6·79	7·07	7·44	7·81	8·18
15/16	5·18	5·58	5·98	6·38	6·78	7·18	7·58	7·98	8·37	8·77
1	5·53	5·96	6·38	6·81	7·23	7·66	8·08	8·51	8·93	9·36

Thickness.	Width.									
	2 7/8	3	3 1/4	3 1/2	3 3/4	4	4 1/4	4 1/2	4 3/4	5
Inch.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
1/8	1·22	1·28	1·38	1·49	1·59	1·70	...	...	...	...
3/16	1·83	1·91	2·07	2·23	2·39	2·55	...	...	...	...
1/4	2·44	2·55	2·76	2·98	3·19	3·40	3·61	3·83	4·04	4·25
5/16	3·06	3·19	3·45	3·72	3·98	4·25	4·51	4·78	5·05	5·32
3/8	3·67	3·83	4·14	4·46	4·78	5·10	5·44	5·74	6·06	6·38
7/16	4·28	4·46	4·83	5·21	5·58	5·95	6·32	6·70	7·07	7·44
1/2	4·89	5·10	5·53	5·95	6·38	6·80	7·23	7·66	8·08	8·50
9/16	5·50	5·74	6·22	6·70	7·18	7·66	8·13	8·61	9·09	9·57
5/8	6·11	6·38	6·91	7·44	7·97	8·50	9·04	9·57	10·10	10·63
11/16	6·72	7·02	7·60	8·19	8·78	9·36	9·94	10·52	11·11	11·70
3/4	7·33	7·65	8·29	8·93	9·56	10·20	10·85	11·48	12·12	12·76
13/16	7·95	8·29	8·98	9·68	10·37	11·06	11·75	12·44	13·13	13·82
7/8	8·55	8·93	9·67	10·41	11·16	11·90	12·65	13·40	14·14	14·89
15/16	9·17	9·57	10·37	11·16	11·96	12·76	13·56	14·35	15·15	15·95
1	9·78	10·21	11·06	11·91	12·76	13·68	14·46	15·31	16·16	17·01

TABLE 95.—WEIGHT OF FLAT BAR STEEL (*continued*).

Thickness.	Width.								
	5½	6	6½	7	8	9	10	11	12
Inch.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
1/4	4·68	5·10	5·53	5·95	6·80	7·66	8·51	9·36	10·21
5/16	5·84	6·38	6·91	7·44	8·50	9·57	10·63	11·70	12·76
3/8	7·02	7·66	8·29	8·93	10·20	11·48	12·76	14·04	15·31
7/16	8·19	8·93	9·68	10·42	11·90	13·39	14·89	16·37	17·86
1/2	9·36	10·21	11·06	11·91	13·60	15·31	17·01	18·71	20·42
9/16	10·53	11·48	12·44	13·40	15·30	17·23	19·14	21·05	22·97
5/8	11·70	12·76	13·82	14·89	17·00	19·14	21·27	23·39	25·52
11/16	12·87	14·04	15·20	16·37	18·70	21·05	23·39	25·73	28·07
3/4	14·04	15·31	16·59	17·86	20·40	22·97	25·32	28·07	30·62
13/16	15·21	16·59	17·97	19·35	22·10	24·88	27·65	30·41	33·18
7/8	16·37	17·86	19·35	20·84	23·80	26·80	29·77	32·75	35·73
15/16	17·54	19·14	20·73	21·33	25·50	28·71	31·90	35·09	38·28
1	18·71	20·41	22·12	23·82	27·20	30·60	34·03	37·43	40·80

TABLE 96.—WEIGHT OF SQUARE STEEL.
Length, 1 Foot.

Side of Square.	Weight.	Side of Square.	Weight.	Side of Square.	Weight.	Side of Square.	Weight.
Inches.	Lbs.	Inches.	Lbs.	Inches.	Lbs.	Inches.	Lbs.
1/8	·053	11/16	1·61	1 7/32	5·06	2 1/2	21·3
5/32	·083	23/32	1·76	1 1/4	5·32	2 5/8	23·5
3/16	·120	3/4	1·91	1 5/16	5·86	2 3/4	25·7
7/32	·163	25/32	2·08	1 3/8	6·43	2 7/8	28·1
1/4	·213	13/16	2·25	1 7/16	7·03	3	30·6
9/32	·269	27/32	2·45	1 1/2	7·71	3 1/4	35·9
5/16	·332	7/8	2·61	1 9/16	8·31	3 1/2	41·7
11/32	·402	29/32	2·81	1 5/8	8·99	3 3/4	47·8
3/8	·479	15/16	2·99	1 11/16	9·80	4	54·4
13/32	·562	31/32	3·19	1 3/4	10·4	4 1/4	61·5
7/16	·651	1	3·40	1 13/16	11·2	4 1/2	68·9
15/32	·748	1 1/32	3·61	1 7/8	12·0	4 3/4	76·8
1/2	·851	1 1/16	3·84	1 15/16	12·8	5	85·1
17/32	·960	1 3/32	4·11	2	13·6	5 1/4	93·8
9/16	1·08	1 1/8	4·31	2 1/8	15·4	5 1/2	102·9
19/32	1·20	1 5/32	4·57	2 1/4	17·2	5 3/4	112·4
5/8	1·33	1 3/16	4·80	2 3/8	19·2	6	122·5
21/32	1·47						

TABLE 97.—WEIGHT OF ROUND STEEL.

Length, 1 Foot.

Diam.	Weight.	Diam.	Weight.	Diam.	Weight.	Diam.	Weight.
Inches.	Lbs.	Inches.	Lbs.	Inches.	Lbs.	Inches.	Cwts.
$\frac{1}{8}$	·042	1	2·68	$2\frac{3}{8}$	15·1	8	1·527
$\frac{5}{32}$	·065	$1\frac{1}{32}$	2·84	$2\frac{7}{16}$	15·9	$8\frac{1}{2}$	1·725
$\frac{3}{16}$	·094	$1\frac{1}{16}$	3·02	$2\frac{1}{2}$	16·8	9	1·932
$\frac{7}{32}$	·128	$1\frac{3}{32}$	3·21	$2\frac{5}{8}$	18·4	$9\frac{1}{2}$	2·154
$\frac{1}{4}$	·167	$1\frac{1}{8}$	3·38	$2\frac{3}{4}$	20·2	10	2·387
$\frac{9}{32}$	·211	$1\frac{5}{32}$	3·57	$2\frac{7}{8}$	22·1	$10\frac{1}{2}$	2·631
$\frac{5}{16}$	·261	$1\frac{3}{16}$	3·77	3	24·1	11	2·887
$\frac{11}{32}$	·317	$1\frac{7}{32}$	3·98	$3\frac{1}{8}$	26·1	$11\frac{1}{2}$	3·152
$\frac{3}{8}$	·376	$1\frac{1}{4}$	4·17	$3\frac{1}{4}$	28·3	12	3·436
$\frac{13}{32}$	·441	$1\frac{9}{32}$	4·38	$3\frac{3}{8}$	30·4	$12\frac{1}{2}$	3·732
$\frac{7}{16}$	·511	$1\frac{5}{16}$	4·61	$3\frac{1}{2}$	32·8	13	4·032
$\frac{15}{32}$	·587	$1\frac{11}{32}$	4·80	$3\frac{5}{8}$	35·1	$13\frac{1}{2}$	4·349
$\frac{1}{2}$	·658	$1\frac{3}{8}$	5·05	$3\frac{3}{4}$	37·6	14	4·676
$\frac{17}{32}$	·755	$1\frac{7}{16}$	5·19	$3\frac{7}{8}$	40·1	$14\frac{1}{2}$	5·317
$\frac{9}{16}$	·845	$1\frac{1}{2}$	6·01	4	42·8	15	5·668
$\frac{19}{32}$	·941	$1\frac{9}{16}$	6·52	$4\frac{1}{4}$	46·3	$15\frac{1}{2}$	5·733
$\frac{5}{8}$	1·04	$1\frac{5}{8}$	7·05	$4\frac{1}{2}$	54·1	16	6·108
$\frac{21}{32}$	1·15	$1\frac{11}{16}$	7·62	$4\frac{3}{4}$	60·3	$16\frac{1}{2}$	6·496
$\frac{11}{16}$	1·29	$1\frac{3}{4}$	8·19	5	66·9	17	6·896
$\frac{23}{32}$	1·30	$1\frac{13}{16}$	8·78	$5\frac{1}{4}$	73·7	$17\frac{1}{2}$	7·308
$\frac{3}{4}$	1·50	$1\frac{7}{8}$	9·39	$5\frac{1}{2}$	80·9	18	7·731
$\frac{25}{32}$	1·63	$1\frac{15}{16}$	10·0	$5\frac{3}{4}$	88·4	19	8·614
$\frac{13}{16}$	1·77	2	10·7	6	96·2	20	9·545
$\frac{27}{32}$	1·90	$2\frac{1}{16}$	11·3			21	10·53
$\frac{7}{8}$	2·04	$2\frac{1}{8}$	12·0	Inches.	Cwts.	22	11·55
$\frac{29}{32}$	2·20	$2\frac{3}{16}$	12·9	$6\frac{1}{2}$	1·008	23	12·63
$\frac{15}{16}$	2·35	$2\frac{1}{4}$	13·6	7	1·169	24	13·74
$\frac{31}{32}$	2·51	$2\frac{5}{16}$	14·3	$7\frac{1}{2}$	1·342		

TABLE 98.—STEEL PLATES: ORDINARY SIZES.

Thickness.	Maximum Area.	Maximum Length.	Maximum Width.	Thickness.	Maximum Area.	Maximum Length.	Maximum Width.
Inch.	Sq. Ft.	Feet.	Feet.	Inch.	Sq. Ft.	Feet.	Feet.
$\frac{1}{16}$	28	14	4	$\frac{7}{16}$	98	40	7
$\frac{3}{32}$	31	18	$4\frac{1}{2}$	$\frac{1}{2}$	105	40	$7\frac{1}{2}$
$\frac{1}{8}$	40	22	5	$\frac{5}{8}$	115	40	$8\frac{1}{4}$
$\frac{5}{32}$	50	25	$5\frac{1}{4}$	$\frac{3}{4}$	125	37	$8\frac{3}{4}$
$\frac{3}{16}$	65	30	$5\frac{1}{2}$	$\frac{7}{8}$	125	34	$8\frac{3}{4}$
$\frac{1}{4}$	72	33	6	1	125	31	$8\frac{3}{4}$
$\frac{5}{16}$	75	35	$6\frac{1}{4}$	$1\frac{1}{8}$	110	28	$8\frac{3}{4}$
$\frac{3}{8}$	85	38	$6\frac{1}{2}$	$1\frac{1}{4}$	110	25	$8\frac{3}{4}$

TABLE 95.—WEIGHT OF FLAT BAR STEEL (*continued*).

Thickness.	Width.								
	$5\frac{1}{2}$	6	$6\frac{1}{2}$	7	8	9	10	11	12
Inch.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
$\frac{1}{4}$	4·68	5·10	5·53	5·95	6·80	7·66	8·51	9·36	10·21
$\frac{5}{16}$	5·84	6·38	6·91	7·44	8·50	9·57	10·63	11·70	12·76
$\frac{3}{8}$	7·02	7·66	8·29	8·93	10·20	11·48	12·76	14·04	15·31
$\frac{7}{16}$	8·19	8·93	9·68	10·42	11·90	13·39	14·89	16·37	17·86
$\frac{1}{2}$	9·36	10·21	11·06	11·91	13·60	15·31	17·01	18·71	20·42
$\frac{9}{16}$	10·53	11·48	12·44	13·40	15·30	17·23	19·14	21·05	22·97
$\frac{5}{8}$	11·70	12·76	13·82	14·89	17·00	19·14	21·27	23·39	25·52
$\frac{11}{16}$	12·87	14·04	15·20	16·37	18·70	21·05	23·39	25·73	28·07
$\frac{3}{4}$	14·04	15·31	16·59	17·86	20·40	22·97	25·32	28·07	30·62
$\frac{13}{16}$	15·21	16·59	17·97	19·35	22·10	24·88	27·65	30·41	33·18
$\frac{7}{8}$	16·37	17·86	19·35	20·84	23·80	26·80	29·77	32·75	35·73
$\frac{15}{16}$	17·54	19·14	20·73	21·33	25·50	28·71	31·90	35·09	38·28
1	18·71	20·41	22·12	23·82	27·20	30·60	34·03	37·43	40·80

TABLE 96.—WEIGHT OF SQUARE STEEL.
Length, 1 Foot.

Side of Square.	Weight.	Side of Square.	Weight.	Side of Square.	Weight.	Side of Square.	Weight.
Inches.	Lbs.	Inches.	Lbs.	Inches.	Lbs.	Inches.	Lbs.
$\frac{1}{8}$	·053	$\frac{11}{16}$	1·61	$1\frac{7}{32}$	5·06	$2\frac{1}{2}$	21·3
$\frac{5}{32}$	·083	$\frac{23}{32}$	1·76	$1\frac{1}{4}$	5·32	$2\frac{5}{8}$	23·5
$\frac{3}{16}$	·120	$\frac{3}{4}$	1·91	$1\frac{5}{16}$	5·86	$2\frac{3}{4}$	25·7
$\frac{7}{32}$	·163	$\frac{25}{32}$	2·08	$1\frac{3}{8}$	6·43	$2\frac{7}{8}$	28·1
$\frac{1}{4}$	·213	$\frac{13}{16}$	2·25	$1\frac{7}{16}$	7·03	3	30·6
$\frac{9}{32}$	·269	$\frac{27}{32}$	2·45	$1\frac{1}{2}$	7·71	$3\frac{1}{4}$	35·9
$\frac{5}{16}$	·332	$\frac{7}{8}$	2·61	$1\frac{9}{16}$	8·31	$3\frac{1}{2}$	41·7
$\frac{11}{32}$	·402	$\frac{29}{32}$	2·81	$1\frac{5}{8}$	8·99	$3\frac{3}{4}$	47·8
$\frac{3}{8}$	·479	$\frac{15}{16}$	2·99	$1\frac{11}{16}$	9·80	4	54·4
$\frac{13}{32}$	·562	$\frac{31}{32}$	3·19	$1\frac{3}{4}$	10·4	$4\frac{1}{4}$	61·5
$\frac{7}{16}$	·651	1	3·40	$1\frac{13}{16}$	11·2	$4\frac{1}{2}$	68·9
$\frac{15}{32}$	·748	$1\frac{1}{32}$	3·61	$1\frac{7}{8}$	12·0	$4\frac{3}{4}$	76·8
$\frac{1}{2}$	·851	$1\frac{1}{16}$	3·84	$1\frac{15}{16}$	12·8	5	85·1
$\frac{17}{32}$	·960	$1\frac{3}{32}$	4·11	2	13·6	$5\frac{1}{4}$	93·8
$\frac{9}{16}$	1·08	$1\frac{1}{8}$	4·31	$2\frac{1}{8}$	15·4	$5\frac{1}{2}$	102·9
$\frac{19}{32}$	1·20	$1\frac{5}{32}$	4·57	$2\frac{1}{4}$	17·2	$5\frac{3}{4}$	112·4
$\frac{5}{8}$	1·33	$1\frac{3}{16}$	4·80	$2\frac{3}{8}$	19·2	6	122·5
$\frac{21}{32}$	1·47						

TABLE 17.—WEIGHT OF ROUND STEEL.

Length, 1 Foot.

Diam.	Weight.	Diam.	Weight.	Diam.	Weight.	Diam.	Weight.
Inches.	Lbs.	Inches.	Lbs.	Inches.	Lbs.	Inches.	Cwts.
[illegible]	[illegible]	1	[illegible]	2 3/8	15·1	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	2·84	2 7/16	15·9	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	3·02	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	3·21	[illegible]	18·4	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	3·77	3	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	4·17	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	4	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	Inches.	Cwts.	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

TABLE [illegible].—STEEL PLATES [illegible]

Thickness.	[illegible]	[illegible]	[illegible]	[illegible]
Inch.	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

ABLE 99.—WEIGHT PER SQUARE FOOT OF STEEL SHEETS AND PLATES.

(The Steel Pipe Company.)

Thickness.			Weight per Square Foot. Pounds.	Thickness.			Weight per Square Foot. Pounds.
Inch.	Inch.	Imperial Standard Gauge.		Inch.	Inch.	Imperial Standard Gauge.	
·0625	$\frac{1}{16}$	...	2·55	·21875	$\frac{7}{32}$	...	8·97
·064	...	16	2·61	·232	...	4	9·46
·072	...	15	2·94	·25	$\frac{1}{4}$	...	10·20
·080	...	14	3·26	·252	...	3	10·28
·092	...	13	3·75	·276	...	2	11·26
·09375	$\frac{3}{32}$	...	3·87	·300	...	1	12·24
·104	...	12	4·24	·3125	$\frac{5}{16}$	...	12·75
·116	...	11	4·73	·375	$\frac{3}{8}$	...	15·30
·125	$\frac{1}{8}$	...	5·10	·4375	$\frac{7}{16}$	...	17·85
·128	...	10	5·22	·500	$\frac{1}{2}$	...	20·40
·144	...	9	5·87	·5625	$\frac{9}{16}$	...	22·95
·15625	$\frac{5}{32}$	...	6·37	·625	$\frac{5}{8}$	...	25·50
·160	...	8	6·53	·6875	$\frac{11}{16}$	...	28·05
·176	...	7	7·18	·75	$\frac{3}{4}$	...	30·60
·1875	$\frac{3}{16}$	...	7·65	·875	$\frac{7}{8}$	...	35·70
·192	...	6	7·83	1·00	1	...	40·80
·212	...	5	8·65				

TABLE 100.—CHISEL STEEL: WEIGHT.

Length, 1 Foot.

Diameter across the Sides.	Weight.		Diameter across the Sides.	Weight.	
	Hexagonal Section.	Octagonal Section.		Hexagonal Section.	Octagonal Section.
Inches.	Pounds.	Pounds.	Inches.	Pounds.	Pounds.
$\frac{3}{8}$	·414	·396	1	2·94	2·82
$\frac{1}{2}$	·736	·704	$1\frac{1}{8}$	3·73	3·56
$\frac{5}{8}$	1·15	1·10	$1\frac{1}{4}$	4·60	4·40
$\frac{3}{4}$	1·66	1·58	$1\frac{3}{8}$	5·57	5·32
$\frac{7}{8}$	2·25	2·16	$1\frac{1}{2}$	6·63	6·34

OVAL FLAT SECTION.

Width × Thickness.	Weight.
Inches.	Pounds.
$\frac{3}{4} \times \frac{3}{8}$	·853
$1 \times \frac{1}{2}$	1·52
$1\frac{1}{4} \times \frac{5}{8}$	2·37

TABLE 101.—SIZES, WEIGHTS, LENGTHS, AND BREAKING STRESS OF IRON WIRE.

Issued by the Iron and Steel Wire Manufacturers' Association, January 15, 1884.

(Imperial Standard Wire-Gauge.)

Size on Wire Gauge.	Diameter.		Sectional Area.	Weight of		Length of Cwt.	Breaking Stress.	
	Inch.	Millimetres.	Sq. Ins.	100 Yards.	Mile.		Annealed.	Bright.
				Lbs.	Lbs.	Yards.	Lbs.	Lbs.
7/0	·500	12·7	·1963	193·4	3404	58	10470	15700
6/0	·464	11·8	·1691	166·5	2930	67	9017	13525
5/0	·432	11	·1466	144·4	2541	78	7814	11725
4/0	·400	10·2	·1257	123·8	2179	91	6702	10052
3/0	·372	9·4	·1087	107·1	1885	105	5796	8694
2/0	·348	8·8	·0951	93·7	1649	120	5072	7608
1/0	·324	8·2	·0824	81·2	1429	138	4397	6595
1	·300	7·6	·0707	69·6	1225	161	3770	5655
2	·276	7	·0598	58·9	1037	190	3190	4785
3	·252	6·4	·0499	49·1	864	228	2660	3990
4	·232	5·9	·0423	41·6	732	269	2254	3381
5	·212	5·4	·0353	34·8	612	322	1883	2824
6	·192	4·9	·0290	28·5	502	393	1544	2316
7	·176	4·5	·0243	24	422	467	1298	1946
8	·160	4·1	·0201	19·8	348	566	1072	1608
9	·144	3·7	·0163	16	282	700	869	1303
10	·128	3·3	·0129	12·7	223	882	687	1030
11	·116	3	·0106	10·4	183	1077	564	845
12	·104	2·6	·0085	8·4	148	1333	454	680
13	·092	2·3	·0066	6·5	114	1723	355	532
14	·080	2	·0050	5	88	2240	268	402
15	·072	1·8	·0041	4	70	2800	218	326
16	·064	1·6	·0032	3·2	56	3500	172	257
17	·056	1·4	·0025	2·4	42	4667	131	197
18	·048	1·2	·0018	1·8	32	6222	97	145
19	·040	1	·0013	1·2	21	9333	67	100
20	·036	0·9	·0010	1	18	11200	55	82

Indian Government Telegraphs.

TELEGRAPH WIRES FOR LINES AND CABLES.

The data for inspection as to size, weight, tensile strength, and ductility, for all sizes of telegraph wires in use by the Indian Government, are given in the Tables 102 and 103, for line wire and cable wire. The wires are of iron, galvanised. In testing the wire for tensile strength, it is loaded by direct weight vertically, and is required at first to lift a weight equal to $\frac{8}{10}$ths of the maximum proof load. If the wire supports the load without failure, the load is gradually augmented by four successive advances, until the wire fails or the maximum load is reached. Testing for ductility, the piece of wire, after failure by load, or after supporting the maximum load, is gripped by two vices and twisted. The vices are 6 inches apart for sizes above 150 pounds per mile ; and 3 inches apart for sizes of 150 pounds or less. The number of twists applied is reduced as the proportional resistance to load is greater, according to the scale of loads and relative twists given in the Tables.

A margin of 1½ per cent. deviation either way from the required weight of wire, weighing 600 pounds per mile and upwards is allowed ; and for wires of less weight, 2 per cent. is allowed.

Weld joints are not allowed in cable-wire, except in the case of cable-wire weighing 900 pounds per mile, sent to Calcutta, in which, if in coils of from 400 to 500 pounds weight, one weld may be introduced.

The maximum resistances per inch of wires, at 60° F.—not to be exceeded—are as follows :—

No.	Units.	No.	Units.
1	4·5	9½	18
3½	6·5	12½	36
4½	7·25	15½	72
5	8	16	90
5½	9	16	108
7	12		

The wires are to bear winding round bars of different diameters, without cracking, as follows :—

Nos.	Bars.
3½ and 4½	4 inches in diameter.
5 „ 5½	2½ „ „
7 „ 9½	2 „ „
12½ „ 15½	1 „ „
16 „ 17	½ „ „

TABLE 102.—GALVANISED IRON TELEGRAPH WIRES: STANDARD SIZES, WEIGHTS AND TESTS.

(India Stores Department.)

LINE WIRE.

Nominal Size.	Diameter.	Weight per Mile.	Weight of Ten Feet.	Tests for Strength and Ductility.										Weight of each Coil.	
				Load.	Twists.	Load.	Twists.	Load.	Twists.	Load.	Twists.	Load.	Twists.	Minimum.	Maximum.
Nos.	Inch.	Lbs.	Lbs.	Lbs.		Lbs.		Lbs.		Lbs.		Lbs.		Lbs.	Lbs.
1	·2960	1200	2·272	3700	11	3800	10	3900	9	4000	8	4100	7	100	120
3½	·2547	900	1·704	2775	14	2850	13	2925	12	3000	11	3076	10	95	105
4½	·2325	750	1·420	2312	15	2375	14	2437	13	2500	12	2562	11	95	105
5	·2205	675	1·278	2081	16	2137	15	2193	14	2250	13	2306	12	95	105
5½	·2079	600	1·136	1850	17	1900	16	1950	15	2000	14	2050	13	95	105
7	·1801	450	·852	1388	19	1425	18	1460	17	1500	16	1538	15	80	105
9½	·1470	300	·568	925	24	950	22	975	21	1000	19	1025	18	70	80
12½	·1039	150	·284	462	17	475	16	487	15	500	14	512	13	70	80
15½	·0735	75	·142	208	24	214	23	219	21	225	19	231	18	35	40
16	·0657	60	·113	167	26	171	25	176	23	180	22	185	20	35	40
17	·0600	50	·095	152	30	157	28	162	26	167	24	172	22	35	40

TABLE 103.—GALVANISED TELEGRAPH WIRES: STANDARD SIZES, WEIGHTS AND TESTS.

(India Stores Department.)

CABLE WIRE.

Nominal Size.	Weight per Mile.	Tests for Strength and Ductility.										Weight of each Coil.	
		Load.	Twists.	Load.	Twists.	Load.	Twists.	Load.	Twists.	Load.	Twists.	Minimum.	Maximum.
No.	Lbs.	Lbs.		Lbs.		Lbs.		Lbs.		Lbs.		Lbs.	Lbs.
3	925	3090	10	3165	9	3240	8	3315	7	3390	6	210	230
3½	900	3000	10	3075	9	3150	8	3225	7	3300	6	210	230
4½	750	2500	11	2562	10	2625	9	2687	8	2750	7	150	160
5½	600	2000	12	2050	11	2100	10	2150	9	2200	8	150	160
7	450	1500	14	1540	13	1580	12	1620	11	1660	10	120	130
9½	300	1000	17	1025	16	1050	15	1075	14	1100	13	120	130

TABLE 104.—SHEET AND HOOP-IRON GAUGE.

Issued by the South Staffordshire Iron Masters' Association. March 1, 1884.

Parts of Inch.	No. on Gauge.	Thickness.	Weight of One Square Foot.		Parts of Inch.	No. on Gauge.	Thickness.	Weight of One Square Foot.	
			Iron.	Steel.				Iron.	Steel.
Inch.		Inch.	Lbs.		Inch.		Inch.	Lbs.	
1	15°	1·000	40	40·83		20	·0392	1·57	1·60
	14°	0·9583	38·33	39·13		21	·0349	1·40	1·43
	13°	·9167	36·67	37·44	1/32	22	·0312	1·25	1·28
7/8	12°	·8750	35·00	35·73		23	·0278	1·11	1·13
	11°	·8333	33·33	34·03		24	·0247	·992	1·01
	10°	·7917	31·67	32·33		25	·0220	·883	·901
3/4	9°	·750	30·00	30·63		26	·0196	·784	·800
	8°	·7083	28·33	28·92		27	·0174	·696	·710
	7°	·6666	26·67	27·23	1/64	28	·015625	·625	·638
5/8	6°	·625	25·00	25·52		29	·0139	·556	·568
	5°	·5883	23·33	23·82		30	·0123	·492	·502
	4°	·5416	21·67	22·12		31	·0110	·440	·449
1/2	3°	·500	20·00	20·42		32	·0098	·392	·400
	2°	·4452	18·33	18·69		33	·0087	·349	·356
	1°	·3964	16·67	17·02		34	·0077	·308	·314
	1	·3532	15·00	15·31		35	·0069	·276	·282
	2	·3147	13·33	13·61		36	·0061	·244	·249
	3	·2804	11·67	12·01		37	·0054	·216	·221
1/4	4	·250	10·00	10·21		38	·0048	·192	·196
	5	·2225	8·90	9·08		39	·0043	·172	·176
	6	·1981	7·92	8·09		40	·00386	·154	·157
	7	·1764	7·06	7·20		41	·00343	·138	·140
	8	·1570	6·38	6·52		42	·00306	·123	·126
	9	·1398	6·51	6·65		43	·00272	·109	·111
1/8	10	·1250	5·00	5·10		44	·00242	·097	·099
	11	·1113	4·45	4·54		45	·00215	·086	·088
	12	·0991	3·97	4·05		46	·00192	·077	·079
	13	·0882	3·53	3·55		47	·00170	·068	·069
	14	·0785	3·14	3·21		48	·00152	·061	·062
	15	·0699	2·80	2·86		49	·00135	·054	·055
1/16	16	·0625	2·50	2·55		50	·00120	·048	·049
	17	·0556	2·23	2·27		51	·00107	·043	·044
	18	·0495	1·98	2·02		52	·00095	·038	·039
	19	·0440	1·76	1·80					

TABLE 105.—LAP-WELDED
(Andrew and
WEIGHT OF ONE

Thickness by Imperial Wire Gauge.			External			
			1	1⅛	1¼	1⅜
Wire Gauge.	Inches.	Millimetres.	Lbs.	Lbs.	Lbs.	Lbs.
16	·064	1·626	0·627	0·711	...	...
15	·072	1·829	0·700	0·794	0·888	0·982
14	·080	2·032	0·771	0·875	0·980	1·085
13	·092	2·337	0·875	0·995	**1·116**	**1·236**
12	·104	2·642	0·976	1·112	1·248	1·384
11	·116	2·946	1·074	1·226	1·377	1·529
10	·128	3·251	1·169	1·336	1·504	1·671
9	·144	3·658	1·291	1·479	1·668	1·856
8	·160	4·064	1·407	1·617	1·826	2·036
7	·176	4·470	1·519	1·749	1·979	2·210
6	·192	4·877	1·624	1·876	2·127	2·378
5	·212	5·385	1·749	2·027	2·304	2·582
4	·232	5·893	1·866	2·169	2·473	2·777
3	·252	6·401	1·974	2·304	2·634	2·963
2	·276	7·010	2·092	2·454	2·815	3·176
1	·300	7·620	2·199	2·592	2·984	3·377
⅛ in.	·125	3·175	1·145	1·309	1·473	1·636
3/16 ,,	·187	4·762	1·595	1·841	2·086	2·332
¼ ,,	·250	6·350	1·963	2·291	2·618	2·945
5/16 ,,	·313	7·937	2·250	2·659	3·068	3·477
⅜ ,,	·375	9·525	2·454	2·945	3·436	3·927
7/16 ,,	·437	11·112	2·577	3·150	3·723	4·295
½ ,,	·500	12·700	2·618	3·272	3·927	4·581

Note.—The most common thick-

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* The weight per lineal foot of a steel tube is given by multiply-

IRON BOILER TUBES.*
James Stewart.)

FOOT IN LENGTH.

Diameter in Inches.							
1½	1⅝	1¾	1⅞	2	2⅛	2¼	2⅜
Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
...	...	...	...	...	...	...	...
1·077	1·171	1·265	1·359	...	...	...	...
1·190	1·294	1·399	1·504	1·608	1·713	1·818	...
1·356	**1·477**	**1·597**	**1·718**	1·838	1·959	2·079	2·199
1·520	1·656	1·793	1·929	**2·065**	**2·201**	**2·337**	2·473
1·681	1·833	1·985	2·137	2·288	2·440	2·592	**2·744**
1·839	2·007	2·174	2·342	2·509	2·677	2·844	3·012
2·045	2·233	2·422	2·610	2·799	2·987	3·176	3·364
2·245	2·455	2·664	2·873	3·083	3·292	3·502	3·711
2·440	2·671	2·901	3·131	3·362	3·592	3·822	4·053
2·630	2·881	3·132	3·384	3·635	3·886	4·138	4·389
2·859	3·137	3·414	3·692	3·969	4·247	4·524	4·802
3·081	3·384	3·688	3·992	4·295	4·599	4·903	5·206
3·293	3·623	3·953	4·283	4·613	4·943	5·273	5·602
3·538	3·899	4·260	4·621	4·983	5·344	5·705	6·067
3·770	4·163	4·555	4·948	5·341	5·733	6·126	6·519
1·800	1·963	2·127	2·291	2·454	2·618	2·782	2·945
2·577	2·822	3·068	3·313	3·559	3·804	4·050	4·295
3·272	3·600	3·927	4·254	4·581	4·909	5·236	5·563
3·886	4·295	4·704	5·113	5·522	5·931	6·340	6·749
4·418	4·909	5·400	5·890	6·381	6·872	7·363	7·854
4·868	5·440	6·013	6·586	7·159	7·731	8·304	3·877
5·236	5·890	6·545	7·199	7·854	8·508	9·163	9·817

nesses are printed in dark figures.
ing the tabular weight of a like wrought-iron tube by 1·021.

TABLE 105.—LAP-WELDED IRON
(Andrew and

WEIGHT OF ONE

Thickness by Imperial Wire Gauge.	External Diameter						
	$2\frac{1}{2}$	$2\frac{5}{8}$	$2\frac{3}{4}$	$2\frac{7}{8}$	3	$3\frac{1}{8}$	$3\frac{1}{4}$
Wire Gauge.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
16	...	...	...	...	...	...	...
15	...	...	...	...	...	...	...
14	...	...	...	...	...	...	...
13	2·320	2·440	2·561	2·681	2·802	...	...
12	2·609	2·745	2·882	3·018	3·154	3·290	3·426
11	**2·896**	**3·048**	**3·200**	**3·351**	**3·503**	3·655	3·807
10	3·179	3·347	3·514	3·682	3·850	**4·017**	**4·185**
9	3·553	3·741	3·930	4·118	4·307	4·495	4·684
8	3·921	4·130	4·339	4·549	4·758	4·968	5·177
7	4·283	4·514	4·744	4·974	5·205	5·435	5·665
6	4·640	4·892	5·143	5·394	5·646	5·897	6·148
5	5·079	5·357	5·634	5·912	6·189	6·467	6·744
4	5·510	5·814	6·117	6·421	6·725	7·028	7·332
3	5·932	6·262	6·592	6·922	7·252	7·582	7·911
2	6·428	6·789	7·150	7·512	7·873	8·234	8·596
1	6·911	7·304	7·697	8·090	8·482	8·875	9·268
$\frac{1}{8}$ in.	3·109	3·272	3·436	3·600	3·763	3·927	4·091
$\frac{3}{16}$,,	4·541	4·786	5·031	5·277	5·522	5·768	6·013
$\frac{1}{4}$,,	5·890	6·218	6·545	6·872	7·200	7·527	7·854
$\frac{5}{16}$,,	7·159	7·568	7·977	8·386	8·795	9·204	9·613
$\frac{3}{8}$,,	8·345	8·836	9·327	9·818	10·308	10·799	11·290
$\frac{7}{16}$,,	9·449	10·022	10·595	11·167	11·740	12·313	12·885
$\frac{1}{2}$,,	10·472	11·126	11·781	12·435	13·090	13·744	14·399

Note.—The most common thick-

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* The weight per lineal foot of a steel tube is given by multi-

BOILER TUBES*—*continued.*
James Stewart.)

FOOT IN LENGTH.

Diameter in Inches.								
$3\frac{3}{8}$	$3\frac{1}{2}$	$3\frac{5}{8}$	$3\frac{3}{4}$	$3\frac{7}{8}$	4	$4\frac{1}{4}$	$4\frac{1}{2}$	$4\frac{3}{4}$
Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...
3·562	3·698	3·835	3·971	4·107	...	...	...	...
3·959	4·111	4·262	4·414	4·566	4·718	5·022	5·325	...
4·352	**4·520**	**4·687**	**4·855**	5·022	5·190	5·525	5·860	6·195
4·872	5·061	5·249	5·438	**5·626**	**5·815**	**6·192**	**6·569**	6·946
5·387	5·596	5·806	6·015	6·224	6·434	6·853	7·272	**7·690**
5·896	6·126	6·357	6·587	6·817	7·048	7·509	7·969	8·430
6·400	6·651	6·902	7·154	7·405	7·656	8·159	8·662	9·164
7·022	7·299	7·577	7·854	8·132	8·410	8·965	9·520	10·075
7·636	7·940	8·243	8·547	8·851	9·154	9·762	10·369	10·976
8·241	8·571	8·901	9·231	9·561	9·891	10·550	11·210	11·870
8·957	9·318	9·679	10·041	10·402	10·763	11·486	12·208	12·931
9·660	10·053	10·446	10·838	11·231	11·624	12·409	13·195	13·980
4·254	4·418	4·581	4·745	4·908	5·072	5·400	5·727	6·054
6·259	6·504	6·750	6·995	7·240	7·486	7·977	8·468	8·959
8·181	8·508	8·836	9·163	9·490	9·817	10·472	11·126	11·781
10·022	10·431	10·840	11·249	11·658	12·067	12·885	13·704	14·522
11·781	12·272	12·763	13·254	13·745	14·235	15·217	16·199	17·181
13·458	14·031	14·604	15·176	15·749	16·322	17·467	18·612	19·758
15·053	15·708	16·362	17·017	17·671	18·326	19·635	20·944	22·253

nesses are printed in dark figures.
plying the tabular weight of a like wrought-iron tube by 1·021.

TABLE 105.—LAP-WELDED IRON (Andrew and

WEIGHT OF ONE

Thickness by Imperial Wire Gauge.	External						
	5	5¼	5½	5¾	6	6¼	6½
Wire Gauge.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
16	...	...	...	...	...	...	...
15	...	...	...	...	...	...	...
14	...	...	...	...	...	...	...
13	...	...	...	...	...	...	...
12	...	...	...	...	...	...	...
11	...	...	...	...	...	...	...
10	6·530	6·866	...	...	...	...	...
9	7·323	7·700	8·077	8·454	8·831	9·208	9·585
8	**8·109**	**8·528**	8·947	9·366	9·785	10·204	10·623
7	8·891	9·352	**9·812**	**10·273**	**10·734**	**11·195**	**11·655**
6	9·667	10·170	10·672	11·175	11·678	12·180	12·683
5	10·630	11·185	11·740	12·295	12·850	13·405	13·960
4	11·584	12·191	12·798	13·406	14·013	14·621	15·228
3	12·530	13·189	13·849	14·509	15·169	15·828	16·488
2	13·654	14·376	15·099	15·821	16·544	17·266	17·989
1	14·765	15·551	16·336	17·122	17·907	18·692	19·478
⅛ in.	6·381	6·709	7·036	7·363	7·690	8·017	8·345
$\frac{3}{16}$,,	9·450	9·940	10·431	10·922	11·413	11·904	12·395
¼ ,,	12·435	13·090	13·744	14·399	15·053	15·708	16·362
$\frac{5}{16}$,,	15·340	16·158	16·976	17·794	18·612	19·430	20·249
⅜ ,,	18·162	19·144	20·126	21·108	22·090	23·071	24·053
$\frac{7}{16}$,,	20·903	22·048	23·194	24·339	25·485	26·630	27·775
½ ,,	23·562	24·871	26·180	27·489	28·798	30·107	31·416

Note.—The most common thick-

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* The weight per lineal foot of a steel tube is given by multi-

BOILER TUBES*—*continued.*
James Stewart.)

FOOT IN LENGTH.

Diameter in Inches.

6¾	7	7¼	7½	7¾	8	8¼	8½	8¾
Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...
9·962	10·339	...	...	...	...	...	...	...
11·042	11·460	...	...	...	...	...	...	...
12·116	**12·577**	13·038	13·499	13·959	14·420	14·880	15·345	15·815
13·186	13·688	14·191	14·694	15·196	15·699	16·204	16·710	17·216
14·515	15·070	**15·625**	**16·180**	**16·735**	**17·290**	17·845	18·400	18·955
15·835	16·443	17·050	17·658	18·265	18·872	19·480	20·087	20·694
17·148	17·807	18·467	19·127	19·787	20·446	**21·106**	**21·766**	**22·426**
18·712	19·434	20·157	20·879	21·602	22·324	23·047	23·769	24·492
20·263	21·048	21·834	22·619	23·405	24·190	24·976	25·761	26·546
8·672	8·999	9·327	9·654	9·981	10·308	10·636	10·963	11·290
12·886	13·376	13·867	14·358	14·849	15·340	15·831	16·322	16·813
17·017	17·671	18·326	18·980	19·635	20·289	20·944	21·598	22·253
21·067	21·885	22·703	23·521	24·339	25·157	25·975	26·704	27·612
25·035	26·017	26·998	27·980	28·962	29·944	30·925	31·907	32·889
28·921	30·066	31·212	32·357	33·502	34·648	35·793	36·938	38·084
32·725	34·034	35·343	36·652	37·961	39·270	40·579	41·888	43·197

nesses are printed in dark figures.
plying the tabular weight of a like wrought iron tube by 1·021

TABLE 105.—LAP-WELDED IRON
(Andrew and

WEIGHT OF ONE

Thickness by Imperial Wire Gauge.			External		
			9	$9\frac{1}{4}$	$9\frac{1}{2}$
Wire Gauge.	Inches.	Millimetres.	Lbs.	Lbs.	Lbs.
16	·064	1·626	...	...	...
15	·072	1·829	...	...	...
14	·080	2·032	...	...	...
13	·092	2·337	...	...	...
12	·104	2·642	...	...	...
11	·116	2·946	...	...	...
10	·128	3·251	...	...	...
9	·144	3·658	...	...	...
8	·160	4·064	...	...	...
7	·176	4·470	16·290	16·770	17·255
6	·192	4·877	17·722	18·230	18·738
5	·212	5·385	19·510	20·065	20·620
4	·232	5·893	21·302	21·909	22·517
3	·252	6·401	**23·085**	**23·745**	**24·405**
2	·276	7·010	25·215	25·937	26·660
1	·300	7·620	27·332	28·117	28·903
$\frac{1}{8}$ in.	·125	3·175	11·617	11·945	12·272
$\frac{3}{16}$,,	·187	4·762	17·303	17·794	18·285
$\frac{1}{4}$,,	·250	6·350	22·907	23·562	24·216
$\frac{5}{16}$,,	·313	7·937	28·430	29·248	30·066
$\frac{3}{8}$,,	·375	9·525	33·871	34·852	35·834
$\frac{7}{16}$,,	·437	11·112	39·229	40·375	41·520
$\frac{1}{2}$,,	·500	12·700	44·506	45·815	47·124

Note.—The most common thick-

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* The weight per lineal foot of a steel tube is given by multi-

BOILER TUBES*—*continued.*
James Stewart.)

FOOT IN LENGTH.

Diameter in Inches.							
9¾	**10**	**10¼**	**10½**	**10¾**	**11**	**11½**	**12**
Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
17·745	18·240	...	...	...	...	...	...
19·250	19·760	...	...	...	...	...	...
21·175	21·730	...	...	...	...	...	...
23·124	23·731	24·35	25·00	25·70	26·45	28·00	29·50
25·065	**25·724**	26·28	26·88	27·51	28·15	29·45	30·80
27·382	28·105	**28·80**	**29·50**	30·22	30·95	32·45	33·95
29·688	30·463	31·30	32·17	**33·07**	**34·00**	**35·95**	**38·00**
12·599	12·926	13·25	13·60	14·00	14·43	15·30	16·20
18·776	19·267	19·74	20·24	20·77	21·30	22·40	23·50
24·871	25·525	26·20	33·90	34·65	35·40	36·90	38·45
30·884	31·702	32·50	33·32	34·15	35·00	36·75	28·50
36·816	37·798	38·80	39·85	41·10	42·20	44·67	47·17
42·665	43·811	45·00	46·03	47·15	48·30	50·70	53·15
48·433	49·742	51·25	52·78	55·00	56·50	58·00	60·50

nesses are printed in dark figures.
plying the tabular weight of a like wrought-iron tube by 1·021.

TABLE 106.—FERRULES FOR BOILER TUBES, IRON AND STEEL.

(Howell & Co.)

External Diameter at Larger End.	Thickness by B. W. G.		Length.	External Diameter at Larger End.	Thickness by B. W. G.		Length.
	Iron.	Steel.			Iron.	Steel.	
Inches.	No.	No.	Inches.	Inches.	No.	No.	Inches.
1½	14	15	1	2⅞	10	11	1¼
1⅝	13	14	1⅛	3	10	11	1¼
1¾	12	13	1 3/16	3½	10	11	1 5/16
1⅞	12	13	1 3/16	3¼	10	11	1 5/16
2	12	13	1 3/16	3⅜	9	10	1 5/16
2⅛	11	12	1 3/16	3½	9	10	1 5/16
2¼	11	12	1 3/16	3⅝	9	10	1⅜
2⅜	11	12	1 3/16	3¾	8	9	1⅜
2½	11	12	1¼	3⅞	8	9	1⅜
2⅝	11	12	1¼	4	8	9	1⅜
2¾	11	12	1¼				

TABLE 107.—LAP-WELDED STEEL LOCOMOTIVE TUBES: SIZES AND WEIGHT (National Tube Works Company, U.S.A.).

(Haswell.)

External Diameter.	Thickness.		Weight per Lineal Foot.	External Diameter.	Thickness.		Weight per Lineal Foot.
Inches.	Wire Gauge.	Inch.	Pounds.	Inches.	Wire Gauge.	Inch.	Pounds.
1	14	·083	·81	2¼	12	·109	2·49
1¼	14	·083	1·03	2½	11	·12	3·05
1½	13	·095	1·42	2¾	11	·12	3·37
1¾	12	·109	1·91	3	11	·12	3·68
2	12	·109	2·20				

TABLE 108.—LAP-WELDED CHARCOAL IRON BOILER TUBE (NATIONAL TUBE WORKS COMPANY, U.S.A.).

(Haswell.)

External Diameter.	Thickness.		Weight per Lineal Foot.	External Diameter.	Thickness.		Weight per Lineal Foot.
Inches.	Wire Gauge.	Inch.	Pounds.	Inches.	Wire Gauge.	Inch.	Pounds.
1	15	·072	·71	4	10	·134	5·47
1⅛	15	·072	·80	4¼	10	·134	5·82
1¼	15	·072	·89	4½	10	·134	6·17
$1\frac{5}{16}$	14	·083	1·08	4¾	10	·134	6·53
1⅜	14	·083	1·13	5	9	·148	7·58
1½	14	·083	1·24	5¼	9	·148	7·97
1⅝	13	·095	1·53	5½	9	·148	8·36
1¾	13	·095	1·66	6	8	·165	10·16
1⅞	13	·095	1·78	7	8	·165	11·90
2	13	·095	1·91	8	8	·165	13·65
2⅛	13	·095	2·04	9	7	·18	16·76
2¼	13	·095	2·16	10	6	·203	20·99
2⅜	12	·109	2·61	11	5	·22	25·03
2½	12	·109	2·75	12	4·5	·229	28·46
2¾	12	·109	3·04	13	4	·238	32·06
2⅞	12	·109	3·18	14	3·5	·248	36·00
3	12	·109	3·33	15	3	·259	40·30
3¼	11	·12	3·96	16	2	·284	47·11
3½	11	·12	4·28	17	1	·300	52·89
3¾	11	·12	4·60	18	0	·340	63·32

TABLE 109.—LAP-WELDED WROUGHT-IRON TUBES FOR ARTESIAN WELLS: WEIGHT PER LINEAL FOOT.

(Lloyd and Lloyd.)

SWELLED JOINTS: Screwed together, External and Internal Screws.											
External Diameter, inches	2	2¼	2½	2¾	3	3¼	3½	3¾	4	4¼	Inches.
Thickness, I. W. G., No. .	11	11	11	11	11	10	10	10	9	9	Thickness.
Weight per lineal foot, lbs.	2·347	2·659	2·971	3·283	3·596	4·344	4·693	5·041	5·932	6·316	Weight.
External Diameter, inches	4½	4¾	5	5¼	5½	5¾	6	6½	7		Inches.
Thickness, I. W. G., No. .	9	8	8	8	7	7	7	7	7		Thickness.
Weight per lineal foot, lbs.	6·701	7·871	8·300	8·729	9·963	10·480	10·900	11·836	12·773		Weight.

FLUSH JOINTS: Screwed together, External and Internal Screws.											
External Diameter, inches	2	2¼	2½	2¾	3	3¼	3½	3¾	4	4¼	Inches.
Weight in pounds per lineal foot ¼ inch thick	4·552	5·202	5·852	6·503	7·153	7·803	8·453	9·104	9·754	10·404	Weight.
5/16 ,, ,,	5·480	6·291	7·103	7·914	8·726	9·537	10·349	11·160	11·972	12·784	,,
⅜ ,, ,,	6·340	7·315	8·291	9·266	10·242	11·217	12·193	13·168	14·444	15·119	,,
External Diameter, inches	4½	4¾	5	5¾	5½	5¼	6	6½	7		Inches.
Weight in pounds per lineal foot ¼ inch thick	11·054	11·705	12·355	13·006	13·656	14·306	14·957	16·533	17·558		Weight.
5/16 ,, ,,	13·598	14·407	15·219	16·030	16·843	17·653	18·465	20·088	21·711		,,
⅜ ,, ,,	16·096	17·070	18·046	19·021	19·997	20·972	21·948	23·898	25·850		,,

TABLE 110.—LAP-WELDED IRON PIPES OR TUBES OF LARGE DIAMETER: WEIGHT OF 1 LINEAL FOOT.

(Lloyd and Lloyd.)

Internal Diameter, inches . .		8	9	10	11	12	13	14	15	16	17	18
Weight in pounds per lineal foot .	$\frac{1}{4}$ inch thick	22	25	28	30	33	35	38	41	43	46	48
	$\frac{3}{8}$	35	38	42	46	50	54	58	62	66	70	74
	$\frac{1}{2}$	47	52	58	63	68	73	78	84	89	94	100

Internal Diameter, inches . .		19	20	21	22	23	24	25	26	27	28
Weight in pounds per lineal foot .	$\frac{1}{4}$ inch thick	51	54	56	59	62	64	67	69	72	75
	$\frac{3}{8}$	78	82	86	90	93	97	101	105	109	113
	$\frac{1}{2}$	105	110	115	120	126	131	136	141	147	152

Internal Diameter, inches . .		29	30	31	32	33	34	35	36	37	38
Weight in pounds per lineal foot .	$\frac{1}{4}$ inch thick	77	80	83	85	88	90	93	96	98	101
	$\frac{3}{8}$	117	121	125	129	133	137	140	144	148	152
	$\frac{1}{2}$	157	162	168	173	178	183	188	194	199	204

Internal Diameter, inches . .		39	40	41	42	43	44	45	46	47	48
Weight in pounds per lineal foot .	$\frac{1}{4}$ inch thick	104	106	109	111	114	117	119	122	124	127
	$\frac{3}{8}$	156	160	164	168	172	176	180	184	188	192
	$\frac{1}{2}$	210	215	220	225	230	236	241	246	251	257

Steam-tubes, gas-tubes, and water-tubes, are made to weight, according to the "size" or bore; butt-welded. The weight of tubes of any given size varies very much with different manufacturers. Table 111 gives the average weights of gas-tubes, as made by seven leading manufacturers. "Steam-tubes" and "water-tubes" are made to the same sizes as the gas-tubes, but of different weights. The tubes are proved by hydrostatic pressure, usually according to the following scale:—

Gas-tubes	50 lbs.	per square inch.
Water-tubes	300 lbs.	,, ,,
Steam-tubes . . .	500 lbs.	,, ,,

To find the thickness of a pipe, when the inside or the outside diameter, and the weight per lineal foot, are given.

Let d be the internal diameter, inches, D the external diameter, w the weight of pipe in pounds per lineal foot. Let, also, c be a constant of weight for the same material, say, the weight of a straight bar 1 inch square, 1 foot long, in pounds. Then,

1*st*. *When the internal diameter is given,*

The external diameter, $$D = \sqrt{\frac{w}{\cdot 7854\,c} + d^2} \quad . \quad . \qquad (1)$$

2*nd*. *When the external diameter is given,*

The internal diameter, $$d = \sqrt{D^2 - \frac{w}{\cdot 7854\,c}} \quad . \quad . \qquad (2)$$

The other diameter having been ascertained by one or other of these formulas, half the difference of the external and internal diameters, is the thickness of the pipe.

For example, a lead pipe of 1 inch bore, weighs 70 pounds for a 15-feet length. What is the thickness? The weight w, per lineal foot is $\left(\frac{70}{15} =\right)$ 4·666 pounds; the weight c of a 1-inch square bar, 1 foot long, is 4·944 pounds; and by formula (1), the external diameter D is equal to $\sqrt{\frac{4\cdot 666}{\cdot 7854 \times 4\cdot 944} \times 1^2} = \sqrt{1\cdot 202 + 1} = \sqrt{2\cdot 202} = 1\cdot 484$ inches. Then $1\cdot 484 - 1 = \cdot 484$ inch, one half of which is ·242 inch, nearly $\frac{1}{4}$ inch, the thickness of the lead pipe.

Conversely, taking the same pipe for example, let the external diameter, 1·484, be given, to find the internal diameter. By formula (2), the internal diameter, *d*, is equal to

$$\sqrt{1{\cdot}484^2 - \frac{4{\cdot}666}{{\cdot}7854 \times 4{\cdot}944}} = \sqrt{2{\cdot}202 - 1{\cdot}202} = \sqrt{1} = 1 \text{ inch}$$

bore.

The constants for other metals are given in Table 89, page 221.

TABLE 111.—BUTT-WELDED GAS TUBES AND FITTINGS: AVERAGE WEIGHT.

Tubes.			Fittings.					
Bore.	Weight per 100 Feet.	Length to weigh One Ton.	Weight of Ten Elbows.		Weight of Ten Tees.		Weight of Ten Crosses.	
Inches.	Pounds.	Feet.	Lb.	Oz.	Lb.	Oz.	Lb.	Oz.
$\frac{1}{8}$	26·3	8502	1	1	1	0	1	8
$\frac{1}{4}$	40·5	5532	1	7	1	8	1	14
$\frac{3}{8}$	57·5	3892	1	13	2	4	2	3
$\frac{1}{2}$	82·9	2700	2	15	3	0	3	4
$\frac{3}{4}$	122·0	1836	4	6	5	4	5	11
1	174·9	1281	6	4	7	10	9	2
$1\frac{1}{4}$	244·3	917	10	10	12	15	14	11
$1\frac{1}{2}$	310·2	722	15	8	16	7	18	10
$1\frac{3}{4}$	359·5	623	15	12	20	0	21	4
2	421·0	532	22	6	27	0	31	4
$2\frac{1}{4}$	515·0	435	30	2	32	8	41	4
$2\frac{1}{2}$	610·4	367	46	2	50	15	51	4
$2\frac{3}{4}$	658·8	340	55	10	68	8	80	10
3	759·3	295	73	8	85	5	88	12
$3\frac{1}{2}$	878·4	255	101	0	121	0	129	0
4	1032·3	217	126	0	144	0	158	0

Note 1.—Normal length, 14 feet.

Note 2.—Steam tubes and water tubes also are manufactured of the same bores.

TABLE 112.—STANDARD SIZES OF CONNECTING PIPES OR UNIONS OF GAS METERS.

(Board of Trade, Standards Department.)

Size of Meter.	Boss.			Cap.			Lining.
	Mean Diameter of External Screw.	Number of Threads per Inch.	Internal Diameter.	Mean Diameter of Internal Screw.	Number of Threads per Inch.	Height of Cap.	External Diameter to enter Boss.
Lights.	Inches.	Threads.	Inches.	Inches.	Threads.	Inches.	Inches.
150	3·68	9	3·05	3·65	9	1·20	3·03
100 80	3·00	11	2·30	2·95	11	1·00	2·28
60	2·45	11	2·00	2·40	11	·80	1·98
50	2·25	11	1·80	2·25	11	·70	1·75
30	2·05	11	1·55	2·00	11	·70	1·53
20	1·80	11	1·42	1·75	11	·60	1·40
10	1·45	11	1·05	1·40	11	·60	1·03
5	1·15	14	·83	1·10	14	·50	·81
3	·98	19	·67	·94	19	·50	·65
2 1	·88	19	·57	·84	19	·40	·55
0	·70	19	·50	·66	19	·40	·50

TABLE 113.—IRON WELDED STEAM, GAS, AND WATER PIPES (National Tube Works Company).

(Haswell.)

Internal Diameter.	Thickness.	Weight per Lineal Foot.	Internal Diameter.	Thickness.	Weight per Lineal Foot.
Inches.	Inch.	Pounds.	Inches.	Inch.	Pounds.
¼	·07	·24	5	·26	14·50
½	·09	·42	6	·28	18·76
⅜	·09	·56	7	·30	23·27
½	·11	·84	8	·32	28·18
¾	·11	1·11	9	·34	33·70
1	·13	1·67	10	·37	40·06
1¼	·14	2·24	11	·37	45·02
1½	·14	2·68	12	·37	48·98
2	·15	3·61	13	·37	53·92
2½	·20	5·74	14	·37	57·89
3	·22	7·50	15	·28	47·11
3½	·23	9·00	16	·30	52·89
4	·24	10·66	17	·34	63·32
4½	·25	12·34			

TABLE 114.—COLD DRAWN STEEL TUBES: DIMENSIONS.
(Howell & Co.)

External Diameter.	Thickness in Fractions of an Inch.									Thickness according to the Birmingham Wire Gauge.							
Inches.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	W.G.	W.G.	W.G.	W.G.	W.G.	W.G.	W.G.	W.G.
1/2	1/16	3/32	1/8	...	..	...	...	...	...	...	..	No. 15	No. 14	No. 13	No. 12	No. 11	No. 10
5/8	,,	,,	,,	3/16	...	...	...	...	...	...	No. 16	,,	,,	,,	,,	,,	,,
3/4	,,	,,	,,	,,	1/4	...	...	...	...	...	,,	,,	,,	,,	,,	,,	,,
7/8	,,	,,	,,	,,	,,	...	...	...	...	...	,,	,,	,,	,,	,,	,,	,,
1	,,	,,	,,	,,	,,	...	...	...	...	No. 18	,,	,,	,,	,,	,,	,,	,,
1 1/8	,,	,,	,,	,,	,,	5/16	...	...	...	,,	,,	,,	,,	,,	,,	,,	,,
1 1/4	,,	,,	,,	,,	,,	,,	3/8	...	...	,,	,,	,,	,,	,,	,,	,,	,,
1 3/8	,,	,,	,,	,,	,,	,,	,,	7/16	...	,,	,,	,,	,,	,,	,,	,,	,,
1 1/2	,,	,,	,,	,,	,,	,,	,,	,,	1/2	...	,,	,,	,,	,,	,,	,,	,,
1 5/8	,,	,,	,,	,,	,,	,,	,,	,,	,,	...	,,	,,	,,	,,	,,	,,	,,
1 3/4	,,	,,	,,	,,	,,	,,	,,	,,	,,	...	,,	,,	,,	,,	,,	,,	,,
1 7/8	,,	,,	,,	,,	,,	,,	,,	,,	,,	...	,,	,,	,,	,,	,,	,,	,,
2	,,	,,	,,	,,	,,	,,	,,	,,	,,	...	,,	,,	,,	,,	,,	,,	,,
2 1/8	...	,,	,,	,,	,,	,,	,,	,,	,,	...	...	,,	,,	,,	,,	,,	,,
2 1/4	...	,,	,,	,,	,,	,,	,,	,,	,,	...	...	,,	,,	,,	,,	,,	,,
2 3/8	...	,,	,,	,,	,,	,,	,,	,,	,,	...	...	...	,,	,,	,,	,,	,,
2 1/2	...	,,	,,	,,	,,	,,	,,	,,	,,	...	...	...	,,	,,	,,	,,	,,
2 5/8	...	,,	,,	,,	,,	,,	,,	,,	,,	...	...	...	,,	,,	,,	,,	,,
2 3/4	...	,,	,,	,,	,,	,,	,,	,,	,,	...	...	...	,,	,,	,,	,,	,,
2 7/8	...	,,	,,	,,	,,	,,	,,	,,	,,	...	...	...	...	,,	,,	,,	,,
3	...	,,	,,	,,	,,	,,	,,	,,	,,	...	...	...	...	,,	,,	,,	,,
3 1/8	...	,,	,,	,,	,,	,,	,,	,,	,,	...	...	...	...	...	...	...	...
3 1/4	...	,,	,,	,,	,,	,,	,,	,,	,,	...	...	...	...	...	...	...	...
3 3/8	...	,,	,,	,,	,,	,,	,,	,,	,,	...	...	...	...	...	...	...	...
3 1/2	...	,,	,,	,,	,,	,,	,,	,,	,,	...	...	...	...	...	...	...	...

Note.—Normal length, 20 feet.

STEEL PIPES.

Mild Steel Pipes.

The Steel Pipe Company shew, in the annexed Tables, the relative thickness and weight of pipes of cast-iron, wrought-iron, and steel, for equal strengths :—

TABLE 115.—RELATIVE THICKNESS OF RIVETED PIPES FOR EQUAL STRENGTH.

Metal.	Cast-Iron.	Wrought-Iron.	Steel.
Weight of 1 square foot, 1 inch thick	37·5 lbs.	40 lbs.	40·8 lbs.
Tenacity per square inch . .	18,000 lbs.	48,600 lbs.	72,000 lbs.
Relative strength for equal thicknesses	1	2·7	4
Factor of safety	10	6	5
Relative strength due to factor of safety	1	4·5	8
Reduction in strength due to riveted joints	...	30 per cent.	30 per cent.
Relative strength after reduction for riveted joints . .	1	3·15	5·6
Relative thickness for plates of equal strength	1	·3174	·1786

TABLE 116.—RELATIVE WEIGHT OF PIPES FOR EQUAL STRENGTH.

Metal.	Cast-Iron.	Wrought-Iron.	Steel.
Thickness of plates, weighing 40 lb. per square foot . .	1 066 inches.	1·00 inch.	·9804 inch.
Relative strength for equal weight	1	2·533	3·678
Relative strength due to factor of safety	1	4·22	7·356
Relative strength after reduction for riveted joints . .	1	2·955	5·149
Relative weight of plain cylinders of equal strength . .	1	·3384	·1942
Increase in weight of pipes due to socket and spigot joints .	5·8 per cent.	15 per cent.	15 per cent.
Relative weight of pipes of equal strength . . .	1	·3678	·2111

From the first Table it appears that the resistance of riveted steel pipes to bursting is 5·6 times that of cast-iron pipes of equal thickness. The longitudinal seams of the riveted pipes are double-riveted and are estimated to have 70 per cent. of the strength of the solid undrilled plates. The pipes are united in lengths of from 4 feet to 6 feet, with circular seams of single riveting.

The minimum thickness of welded plates is ⅛ inch.

The weight of steel pipes, complete with sockets, spigots, rivets, lap-joints, and asphalte coating $\frac{1}{32}$ inch thick, is one-fourth of that of cast-iron pipes of equal strength. The coating effectually prevents corrosion. The weight of steel pipes complete as above specified, is given by the formula (1).

Weight of Steel Pipes per Lineal Foot.

$$W = \cdot 33\, d\, w \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

W = weight per lineal foot.
d = diameter in inches.
w = weight of plate or sheet in pounds per square foot.
t = thickness of pipe in inches.
H = working head in feet of water.

Thickness of Pipes and Working Head of Pressure.

$$\text{Cast-iron pipes} \left\{ \begin{array}{ll} t = \cdot 00012\, d\, H & . \quad . \quad . \quad . \quad (2) \\ H = \dfrac{t}{\cdot 00012\, d} & . \quad . \quad . \quad . \quad . \quad (3) \end{array} \right.$$

$$\text{Steel pipes} \quad . \left\{ \begin{array}{ll} t = \cdot 000025\, d\, H & . \quad . \quad . \quad . \quad (4) \\ H = \dfrac{t}{\cdot 000025\, d} & . \quad . \quad . \quad . \quad . \quad (5) \end{array} \right.$$

A 12-inch riveted steel pipe, 8 feet 7 inches long, ⅛ inch thick, was tested under a bursting pressure of 760 lbs. per square inch. It leaked slightly at one of the rivets, and a portion of the caulking slightly yielded. No other sign of damage was visible. The longitudinal lap-joints had 1⅜ inches of lap, with ¾-inch rivets at 1⅞ inches of pitch. It was fitted at each end with a circular flange 2½ inches by 2½ inches by ¼-inch thick. The ultimate tensile strength of the metal was 24 tons per square inch. The stress on the metal was at the rate of 760 × 12 = 9120 lbs. per lineal inch, or (9120 × 4 =) 36480 lbs., or 16·3 tons per square inch of section of both sides together. This is about equal to 70 per cent. of the ultimate resistance, or 16·8 tons per square inch, the strength at the joint ; showing that the calculated ultimate resistance is corroborated by the results of the test.

TABLE 117.—WEIGHT OF RIVETED STEEL PIPES, WITH PLAIN ENDS.

(The Steel Pipe Company).

Thickness. Inches.	·064	·072	·080	·092	·104	·116	·125	·128	·144	·160	·176	·1875
Imperial Gauge.	16	15	14	13	12	11	$\frac{1}{8}$	10	9	8	7	$\frac{3}{16}$
Diam.	WEIGHT PER LINEAL FOOT.											
Ins.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
3	2·75	3·20	3·50	4·05								
4	3·54	4·04	4·44	5·13								
5	4·33	4·89	5·38	6·21								
6	5·12	5·73	6·32	7·29	8·35	9·42						
7	5·91	6·58	7·26	8·37	9·57	10·78						
8	6·70	7·43	8·20	9·45	10·79	12·14						
9	7·49	8·29	9·14	10·53	12·91	13·50	14·48					
10	8·28	9·12	10·08	11·61	14·13	14·86	15·95					
11	...	9·96	11·02	12·69	15·35	16·22	17·42					
12	...	10·86	11·96	13·77	16·57	17·58	18·89	19·41	22·42	24·94	27·71	29·83
13	...	...	12·90	14·85	17·79	18·94	20·36	20·91	24·10	26·80	29·76	32·01
14	...	...	13·84	15·93	19·01	20·30	21·83	22·42	25·77	28·67	31·81	34·20
15	...	...	...	17·01	20·23	21·67	23·30	23·92	27·44	30·53	33·86	36·37
16	...	...	...	18·10	21·45	23·03	24·77	25·43	29·12	32·40	35·91	38·56
17	...	...	...	...	22·67	24·40	26·24	26·94	30·80	34·26	37·96	40·74
18	...	...	...	...	23·89	25·75	27·71	28·44	32·47	36·13	40·01	42·93
19	...	...	...	...	...	27·11	29·18	29·95	34·15	38·00	42·06	45·11
20	...	...	...	...	...	28·47	30·65	31·45	35·82	39·85	44·11	47·30
21	...	...	...	...	...	...	32·12	32·96	37·50	41·71	46·16	49·48
22	...	...	...	...	...	...	33·59	34·47	39·18	43·58	48·21	51·67
23	...	...	...	...	...	...	35·06	35·97	40·85	45·44	50·26	53·85
24	...	...	...	...	...	...	36·53	37·48	42·53	47·31	52·31	56·04
25	...	...	...	...	...	...	...	38·98	44·20	49·17	54·36	58·22
26	...	...	...	...	...	...	...	40·50	45·88	51·04	56·41	60·41
27	...	...	...	...	...	...	...	42·00	47·56	52·90	58·46	62·60
28	...	...	...	...	...	...	...	43·50	49·23	54·77	60·51	64·78
29	...	...	...	...	...	...	...	45·00	50·91	56·63	62·56	66·96
30	...	...	...	...	...	...	...	46·50	52·58	58·50	64·61	69·15

Note.—Usual lengths, 18 feet to 40 feet.

TABLE 118.—WEIGHT OF RIVETED STEEL PIPES, WITH PLAIN ENDS: TO 36 INCHES IN DIAMETER.

(The Steel Pipe Company.)

Thickness. Inches.	$\frac{1}{8}$	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{11}{16}$	$\frac{3}{4}$
Diam.	WEIGHT PER LINEAL FOOT.										
Ins.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
12	18·9	29·8	40·5								
13	20·3	32·0	43·3								
14	21·8	34·2	46·2								
15	23·8	36·4	49·0	60·3							
16	24·7	38·5	51·8	63·9							
17	26·2	40·7	54·7	67·5							
18	27·7	42·9	57·5	71·0	85·7						
19	29·2	45·1	60·4	74·6	90·0						
20	30·6	47·3	63·2	78·3	94·3						
21	32·1	49·5	66·1	81·8	98·6	112·5					
22	33·6	51·6	68·9	85·4	102·9	117·6					
23	35·0	53·8	71·8	89·0	107·2	122·8					
24	36·5	56·0	74·6	92·6	111·5	127·9	149·0	167·8	186·7	205·9	225·6
25	...	58·2	77·5	96·2	115·8	133·1	154·7	174·2	193·8	213·6	234·0
26	...	60·4	80·3	99·8	120·1	138·2	160·4	180·6	200·9	221·4	242·4
27	...	62·6	83·1	103·4	124·4	143·4	166·1	187·0	208·0	229·2	250·8
28	...	64·8	86·0	107·0	128·7	148·5	171·8	193·4	215·1	237·0	259·3
29	...	66·9	88·8	110·6	133·0	153·7	177·5	199·8	222·2	244·8	267·7
30	...	69·1	91·7	114·2	137·3	158·8	183·2	206·2	229·3	252·5	276·1
31	...	...	94·5	117·8	141·6	164·0	188·9	212·7	236·4	260·3	284·5
32	...	...	97·4	121·4	145·9	169·2	194·6	219·1	243·5	268·1	293·0
33	...	...	100·2	125·0	150·2	174·3	200·3	225·5	250·6	275·9	301·4
34	...	...	103·0	128·6	154·5	179·5	206·0	232·0	257·8	283·7	309·8
35	...	...	105·9	132·2	158·8	184·6	211·7	238·3	264·9	291·4	318·2
36	...	...	108·7	135·8	163·1	189·8	217·4	244·7	272·0	299·2	326·7

The usual lengths to which the riveted steel pipes are constructed, are from 18 feet to 40 feet.

The longitudinal seams of riveted steel pipes, double-riveted, are proved to have a bursting strength equal to 70 per cent. of that of the solid undrilled plates.

TABLE 119.—WEIGHT OF RIVETED STEEL PIPES, WITH PLAIN ENDS: TO 60 INCHES IN DIAMETER.

(The Steel Pipe Company.)

Thickness, Inches.	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{11}{16}$	$\frac{3}{4}$	$\frac{7}{8}$	1
Diam.	WEIGHT PER LINEAL FOOT.										
Ins.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
37	111·5	139·0	167·0	195·0	223·0	251·0	279·0	307·0	343·5		
38	114·0	143·0	171·5	200·0	229·0	257·5	286·0	315·0	352·0		
39	117·0	146·5	176·0	205·0	234·5	264·0	293·0	322·5	360·0		
40	120·0	150·0	180·0	210·0	240·0	270·0	300·0	330·0	370·0		
41	122·5	153·5	184·0	215·0	246·0	277·0	308·0	339·0	380·0		
42	125·0	157·0	188·5	220·0	252·0	284·0	316·0	348·0	390·0		
43	127·5	160·5	193·0	225·5	258·0	291·0	324·0	356·5	399·5		
44	130·0	164·0	197·0	230·5	264·0	298·0	332·0	365·5	409·5	460·0	
45	132·5	167·5	201·5	236·0	270·5	305·0	340·0	374·5	419·0	472·0	
46	135·0	171·0	205·5	241·0	276·5	312·0	348·0	383·0	429·0	484·5	
47	137·5	174·5	210·0	246·0	282·5	319·0	356·0	392·0	439·0	496·5	
48	140·0	178·0	214·5	251·5	289·0	326·0	364·0	401·0	449·0	509·0	576·0
49	...	181·5	218·5	256·5	295·0	333·0	372·0	410·0	459·0	521·0	591·0
50	...	185·0	223·0	262·0	301·0	340·0	380·0	419·0	469·0	533·5	606·0
51	...	188·5	227·0	267·0	307·0	347·0	388·0	428·0	479·0	545·5	621·0
52	...	192·0	231·5	272·0	313·0	354·0	396·0	437·0	489·0	558·0	636·0
53	...	195·5	236·0	277·5	319·0	361·0	404·0	446·0	498·5	570·0	651·0
54	...	199·0	240·0	282·5	325·0	368·0	412·0	454·5	508·5	582·5	666·0
55	...	...	244·5	288·0	331·5	375·0	420·0	463·5	518·0	594·5	681·0
56	...	...	248·5	293·0	337·5	382·0	428·0	472·0	528·0	607·0	696·0
57	...	...	253·0	298·0	343·5	389·0	436·0	481·0	538·0	619·0	711·0
58	...	...	257·5	303·5	350·0	396·0	444·0	490·0	548·0	631·5	726·0
59	...	...	261·5	308·5	356·0	403·0	452·0	499·0	558·0	643·5	741·0
60	...	...	266·0	314·0	362·0	410·0	460·0	508·0	568·0	656·0	756·0

The usual lengths to which the riveted steel pipes are constructed, are from 18 feet to 40 feet.

The longitudinal seams, double-riveted, have 70 per cent. of the strength of the solid plate.

TABLE 120.—WEIGHT OF LAP-WELDED PIPES WITH PLAIN ENDS.

(The Steel Pipe Company)

Thickness. Inches.	·176	·192	·212	·232	·252	·276	·300	·25	·3125	·375	·4375	·500
Imperial Gauge.	7	6	5	4	3	2	1	¼	5/16	3/8	7/16	½
Diam.	WEIGHT PER LINEAL FOOT.											
Ins.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
3	5·97	6·54	7·27	8·00	8·75	9·65	10·57	8·69	11·04	13·53	15·19	18·70
4	7·85	8·59	9·54	10·48	11·44	12·60	13·78	11·36	14·38	17·53	20·76	24·04
5	9·73	10·64	11·80	12·95	14·13	15·55	16·98	14·03	17·70	21·53	25·43	29·38
6	11·61	12·69	14·07	15·43	16·82	18·50	20·18	16·70	21·06	25·54	30·10	34·72
7	13·49	14·73	16·33	17·91	19·51	21·44	23·40	19·37	24·40	29·54	34·77	40·06
8	15·37	16·79	18·60	20·38	22·20	24·40	26·60	22·04	27·74	33·55	39·44	45·40
9	17·25	18·83	20·87	22·86	24·90	27·34	29·80	24·71	31·08	37·55	44·11	50·74
10	19·13	20·89	23·13	25·35	27·40	30·28	33·00	27·38	34·42	41·56	48·78	56·08
11	21·01	22·94	25·40	27·81	30·28	33·23	36·21	30·05	37·76	45·56	53·45	61·42
12	22·89	24·98	27·66	30·29	32·97	36·18	39·41	32·72	41·10	49·57	58·12	66·76
13	24·77	27·03	29·92	32·76	35·66	39·13	42·62	35·39	44·43	53·57	62·79	72·10
14	26·65	29·08	32·19	35·24	38·33	42·07	45·82	38·06	47·77	57·58	67·46	77·43
15	28·53	31·12	34·45	37·72	41·04	45·02	49·03	40·73	51·11	61·58	72·13	82·77
16	30·41	33·18	36·72	40·19	43·74	47·97	52·23	43·40	54·45	65·59	76·80	88·11
17	33·29	35·23	38·98	42·67	46·43	50·92	55·44	46·07	57·78	69·59	81·47	93·45
18	34·17	37·28	41·24	45·15	49·12	53·86	58·64	48·74	61·12	73·60	86·14	98·80
19	36·05	39·33	43·51	47·62	51·81	56·81	61·84	51·40	64·46	77·60	90·81	104·13
20	37·93	41·38	45·77	50·10	54·50	59·76	65·05	54·07	67·80	81·60	95·48	109·47
21	39·81	43·43	48·04	52·58	57·20	62·70	68·25	56·74	71·13	85·61	100·15	114·81
22	41·69	45·47	50·30	55·05	59·88	65·65	71·46	59·41	74·47	89·62	104·82	120·15
23	43·57	47·52	52·57	57·53	62·57	68·60	74·66	62·08	77·81	93·62	109·49	125·45
24	45·45	49·57	54·83	60·01	65·27	71·55	77·87	64·75	81·15	97·63	114·16	130·82
25	47·33	51·62	57·09	62·48	67·96	74·50	81·08	67·42	84·48	101·63	118·83	136·16
26	49·21	53·67	59·36	64·96	70·65	77·44	84·28	70·10	87·82	105·64	123·50	141·50
27	51·09	55·72	61·63	67·43	73·34	80·39	87·49	72·76	91·16	109·64	128·17	146·81
28	52·97	57·77	63·89	69·91	76·03	83·34	90·72	75·44	94·50	113·65	132·84	152·18
29	54·85	59·82	66·16	72·39	78·72	86·28	93·92	78·11	97·83	117·65	137·51	157·52
30	56·73	61·87	68·42	74·86	81·42	89·23	97·13	80·78	101·17	121·66	142·18	162·86

Usual length, 14 feet to 18 feet.

TABLE 121.—ROLLED IRON JOISTS: ESTIMATED

(Measures

Factor of

Reference Number.	Clear Span in Feet, or							
	6	8	10	12	14	16	18	20
No.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
1	90·0	67·4	54·0	45·0	38·6	33·7	30·0	27·0
2	66·6	50·0	40·0	33·3	28·7	25·0	22·2	20·0
3	61·8	46·2	36·6	30·9	26·5	23·1	20·6	18·3
4	50·8	37·9	30·4	25·4	21·7	19·0	16·9	15·2
5	...	43·6	35·0	29·0	25·0	21·8	19·2	17·3
6	45·5	32·8	26·8	21·9	18·7	16·4	14·8	13·1
7	36·2	27·2	21·7	18·1	15·5	13·6	12·1	10·9
8	33·3	25·0	20·0	16·6	14·2	12·5	11·1	10·0
9	24·7	18·5	14·8	12·4	10·6	9·3	8·2	7·4
10	21·6	16·2	13·0	10·8	9·3	8·1	7·2	6·5
11	...	...	...	...	...	...	...	...
12	19·2	14·5	11·6	9·6	8·3	7·2	6·4	5·8
13	...	15·6	12·5	10·4	8·9	7·8	7·0	6·2
14	18·6	14·0	11·2	9·3	8·0	7·0	6·2	5·6
15	13·9	10·5	8·0	7·0	6·0	5·2	4·5	4·2
16	15·4	11·5	9·2	7·7	6·6	5·8	5·1	4·6
17	13·1	9·8	7·8	6·5	5·6	4·9	4·3	4·0
18	9·3	7·0	5·3	4·7	4·0	3·5	3·1	2·8
19	6·4	4·8	3·9	3·2	2·8	2·4	2·1	1·9
20	11·5	8·5	6·8	5·7	4·9	4·3	3·8	3·4
21	7·6	5·7	4·4	3·8	3·2	2·8	2·5	2·3
22	4·1	3·8	2·5	2·1	1·8	1·5	1·4	1·2
23	3·1	2·3	1·9	1·6	1·3	1·2	1·0	0·9
24	1·9	1·3	1·1	0·9	0·8	0·7	0·6	0·5
25	5·5	4·2	3·3	2·8	2·4	2·1	1·8	1·6
26	4·1	3·0	2·4	2·1	1·7	1·5	1·4	1·2
27	2·3	1·7	1·4	1·1	0·9	0·8	0·7	0·67
28	1·7	1·3	1·0	0·9	0·7	0·6	0·57	0·50
29	0·8	0·6	0·5	0·4$\frac{1}{7}$	0·3$\frac{4}{7}$	0·3	0·28	0·25

Note.—For Dimensions and

SAFE PERMANENT DISTRIBUTED LOADS.

Brothers & Co.).

Safety 1-4th.

Distance between Supports.								Reference Number.
22	24	26	28	30	32	34	36	
Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	No.
24·5	22·5	20·8	19·3	18·0	16·8	15·9	15·0	1
18·0	16·7	15·6	14·4	13·3	12·5	11·8	11·1	2
16·8	15·4	14·2	13·2	12·3	11·6	10·9	10·3	3
13·8	12·7	11·7	10·9	10·1	9·5	9·0	8·4	4
15·7	14·2	13·2	12·2	11·0	10·2	9·8	...	5
11·9	10·9	10·1	9·4	8·7	8·5	7·7	7·2	6
9·9	9·0	8·4	7·8	7·2	6·8	6·4	6·0	7
9·0	8·3	7·7	7·0	6·7	6·2	5·8	5·5	8
6·7	6·2	5·7	5·3	4·9	4·6	4·3	4·1	9
5·9	5·4	5·0	4·6	4·3	4·0	3·8	3·6	10
...	...	...	...	...	...	...	...	11
5·3	4·8	4·4	4·1	3·9	...	...	...	12
5·6	5·0	4·6	4·2	...	...	...	...	13
5·1	4·6	4·3	4·0	3·7	...	...	...	14
3·8	3·5	3·2	3·0	2·8	...	...	...	15
4·2	3·8	3·6	3·3	3·1	2·9	2·7	...	16
3·6	3·3	3·0	2·8	2·6	...	...	...	17
2·5	2·3	2·2	2·0	1·9	...	...	...	18
1·8	1·6	1·5	1·4	1·2	...	...	...	19
3·1	2·8	2·6	2·4	2·1	...	...	...	20
2·0	1·9	1·7	1·5	1·3	...	...	...	21
1·1	1·0	0·9	0·8	0·7	...	...	...	22
...	...	...	...	...	...	...	...	23
...	...	...	...	...	...	...	...	24
1·5	1·4	1·3	1·2	1·1	...	...	...	25
1·1	1·0	0·9	0·8	0·7	...	...	...	26
0·60	0·58	0·52	...	...	...	...	...	27
0·41½	0·40	0·38	...	...	...	...	...	28
0·22	0·20	0·18	...	...	...	...	...	29

Weights of Joists, see Table 122.

TABLE 122.—ROLLED IRON JOISTS.

(Measures Brothers & Co.)

Reference Number.	Sectional Dimensions. Depth × Width.	Thickness of		Weight per Lineal Foot.	Stock Lengths.
		Web.	Flanges (average).		
	Inches.	Inch.	Inch.	Pounds.	Feet.
1	$19\frac{3}{4} \times 7\frac{1}{8}$	$\frac{13}{16}$ *b*	$1\frac{1}{16}$	100	16 to 40
2	$17\frac{3}{4} \times 6\frac{3}{4}$	$\frac{11}{16}$	$\frac{15}{16}$	82	16 to 40
3	16×6	$\frac{9}{16}$	$\frac{13}{16}$	62	8 to 40
4	14×6	$\frac{9}{16}$ $\frac{1}{32}$	$\frac{13}{16}$	60	8 to 40
5	$12 \times 7\frac{1}{4}$	...	...	72	16 to 35
6	12×6	$\frac{5}{8}$ $\frac{1}{32}$	$\frac{3}{4}$	56	6 to 40
7	12×5	$\frac{1}{2}$ $\frac{1}{32}$	$\frac{5}{8}$ $\frac{1}{32}$	42	6 to 40
8	10×6	$\frac{1}{2}$	$\frac{7}{8}$	56	7 to 36
9	10×5	$\frac{7}{16}$	$\frac{11}{16}$	36	6 to 40
10	$10 \times 4\frac{1}{2}$	$\frac{7}{16}$	$\frac{9}{16}$	32	6 to 30
11	$8\frac{7}{8} \times 6$	...	...	42	10 to 30
12	$9\frac{1}{2} \times 4\frac{1}{2}$	$\frac{3}{8}$ $\frac{1}{32}$	$\frac{9}{16}$	29	6 to 40
13	$9\frac{1}{4} \times 3\frac{3}{4}$	$\frac{3}{8}$ $\frac{1}{32}$	$\frac{3}{8}$ $\frac{1}{32}$	24	6 to 40
14	8×6	$\frac{1}{2}$ $\frac{1}{32}$	$\frac{1}{2}$	34	6 to 30
15	8×5	$\frac{3}{8}$ $\frac{1}{32}$	$\frac{1}{2}$ $\frac{1}{32}$	29	5 to 40
16	8×4	$\frac{1}{2}$	$\frac{7}{16}$	22	5 to 30
17	$7 \times 3\frac{3}{4}$	$\frac{5}{16}$	$\frac{7}{16}$	20	5 to 40
18	6×5	$\frac{1}{2}$	$\frac{1}{2}$	29	5 to 36
19	$6\frac{1}{4} \times 3\frac{1}{8}$	$\frac{5}{16}$	$\frac{7}{16}$	16	5 to 40
20	$5 \times 4\frac{1}{2}$	$\frac{5}{16}$ $\frac{1}{32}$	$\frac{1}{2}$	23	5 to 36
21	$4\frac{3}{4} \times 3$	$\frac{5}{16}$	$\frac{5}{16}$	13	5 to 36
22	4×3	$\frac{1}{4}$ $\frac{1}{32}$	$\frac{5}{16}$	12	5 to 30
23	3×3	$\frac{3}{16}$ $\frac{1}{32}$	$\frac{5}{16}$ *b*	10	5 to 30
24	$8 \times 2\frac{1}{2}$	$\frac{5}{16}$ $\frac{1}{32}$	$\frac{3}{8}$ $\frac{1}{32}$	15	6 to 30
25	$7 \times 2\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$ $\frac{1}{32}$	14	6 to 30
26	$6\frac{1}{4} \times 2$	$\frac{1}{4}$ *f*	$\frac{3}{8}$	11	5 to 30
27	$4\frac{3}{4} \times 1\frac{3}{4}$	$\frac{3}{16}$ *f*	$\frac{5}{16}$	8	5 to 26
28	$4 \times 1\frac{3}{4}$	$\frac{3}{16}$ *f*	$\frac{5}{16}$	7	5 to 26
29	$3 \times 1\frac{1}{2}$	$\frac{3}{16}$	$\frac{3}{16}$ $\frac{1}{32}$	5	5 to 26

b = bare ; *f* = full.

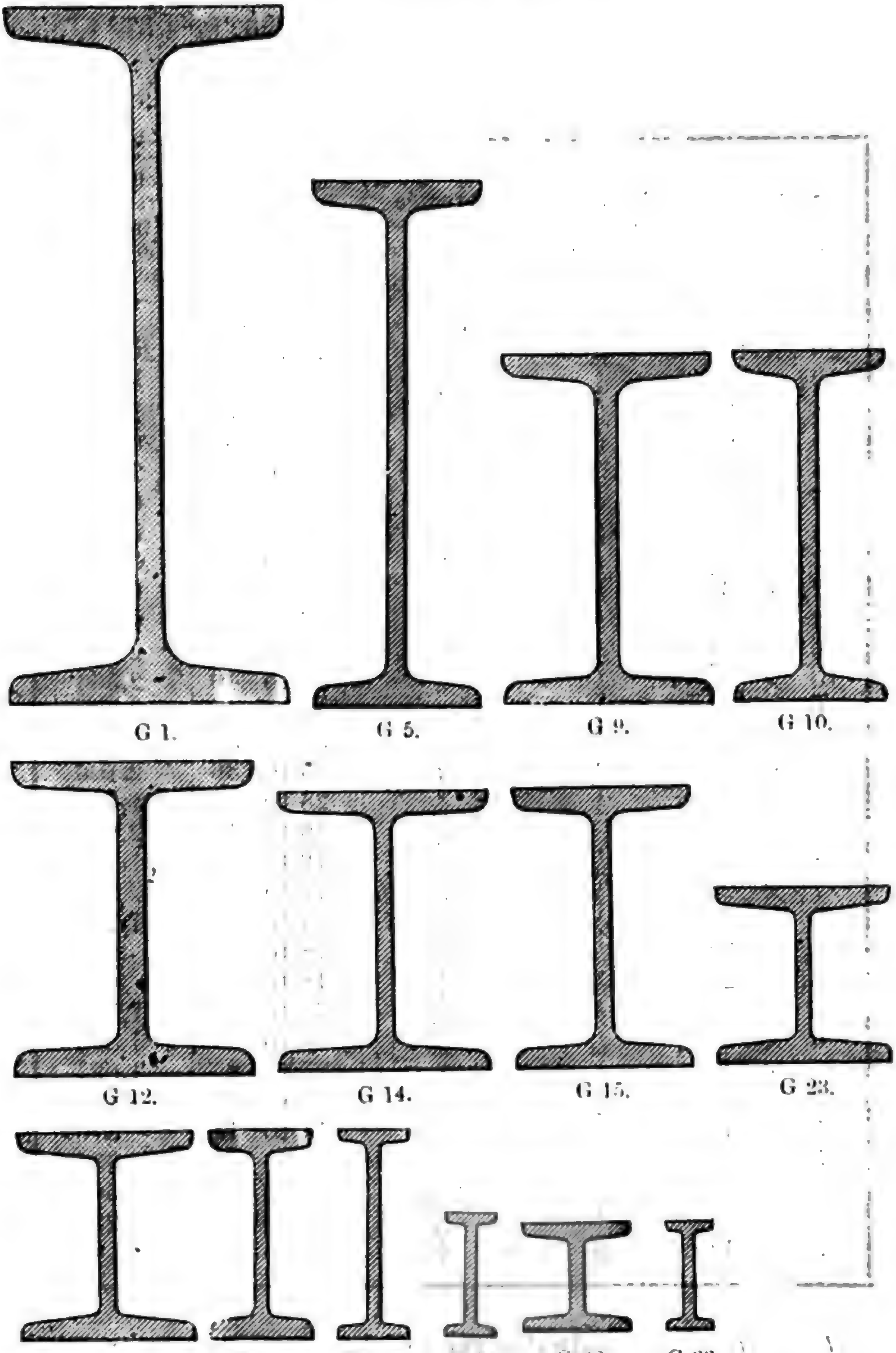
Note.—For Safe Loads, see Table 121.

TABLE 123.—ROLLED IRON JOISTS: CALCULATED BREAKING LOAD AT THE CENTRE.

(Butterley Iron Company.)

Sectional Dimensions. Depth × Width.	Minimum Thickness of Web.	Average Thickness of Flanges.	Weight per Lineal Foot.	Coefficient of Transverse Strength: Loaded at the Middle.
Inches	Inch.	Inch.	Pounds.	
20 × 10	13/16	1¼	140 to 144	20,312
19¾ × 6¼	⅝	¾	69 to 70	8,700
18 × 6¼	⅝	¾	67 to 70	7,704
16 × 6¼	⅝	¾	63 to 66	6,696
16 × 5½	11/16	1	69 to 72	7,644
15 × 5½	⅝	⅞	57 to 60	6,704
14 × 6¼	⅝	¾	59 to 62	5,544
12 × 6¼	⅝	¾	59 to 62	5,064
12 × 6	¾	1	67 to 77	6,048
12 × 5	½	13/16	46 to 50	4,069
10½ × 5½	½	⅝	38 to 41	2,700
10 × 5	½	⅝	36 to 40	2,564
9 × 5½	½	¾	42 to 45	2,902
9 × 4½	½	⅝	33 to 37	2,144
8½ × 4	9/16	¾	33 to 36	2,100
8 × 4½	½	9/16	28 to 30	1,748
8 × 4	13/16	⅞	40 to 42	2,340
8 × 2½	7/16	⅝	19 to 21	1,194
7¼ × 2¼	½	7/16	19 to 21	807
7 × 3½	½	9/16	23 to 25	1,144
6⅜ × 3⅜	7/16	7/16	18 to 20	846
6¼ × 2⅞	7/16	½	18 to 20	825
6 × 6	½	9/16	30 to 32	1,512
6 × 5	7/16	9/16	26 to 28	1,245
6 × 4	½	9/16	23 to 25	1,094
5⅞ × 5	½	½	27 to 29	1,117
5½ × 1¾	⅜	½	11 to 13	375
5 × 1¾	5/16	½	9 to 11	334
4½ × 4	⅜	⅜ 1/32	18 to 18	560
4¼ × 1½	¼	7/16	7 to 9	251
3 × 1⅛	5/32	¼	3 to 4	60

Use of the Table.—Divide the number in the last column by the span in inches; the quotient is the breaking load in tons at the centre.



G 1. G 5. G 9. G 10.

G 12. G 14. G 15. G 23.

G 19. G 20. G 21. G 31. G 32. G 33.

FIGS. 19—32.—Rolled Steel Joists, Table 124 (Dorman, Long, & Co.). Scale 1-8th.

TABLE 124.—ROLLED STEEL JOISTS (Dorman, Long, & Co.).

Reference Number.	Normal Dimensions. Depth × Width.	Actual Dimensions. Depth × Width.	Thickness of Web.	Mean Thickness of Flanges.	Sectional Area.	Weight per Lineal Foot.	Distributed Load for One Foot Span.		
							Factor 3.	Factor 4.	Factor 5.
No.	Inches.	Inches.	Inch.	Inch.	Sq. Inches.	Pounds.	Tons.	Tons.	Tons.
G 1 +	20 × 8	20 × 8·26	·76	·97	29·67	100	1297·84	973·38	778·70
G 1	20 × 8	20 × 8·18	·68	·97	28·24	95	1261·81	946·36	757·09
G 1 —	20 × 8	20 × 8·11	·61	·97	26·78	90	1226·73	920·05	736·04
G 2 +	18 × 7	18 × 7·11	·81	·94	26·46	90	992·76	744·13	595·30
G 2	18 × 7	18 × 7·10	·71	·94	24·67	84	954·16	715·62	572·49
G 2 —	18 × 7	18 × 6·90	·61	·94	22·88	78	915·76	686·82	549·45
G 3 +	16 × 6	16 × 6·12	·71	·82	20·18	68	669·60	502·2	401·76
G 3	16 × 6	16 × 6·06	·64	·82	19·15	64·5	649·87	487·41	389·92
G 3 —	16 × 6	16 × 5·95	·54	·82	17·51	59	618·93	464·19	371·35
G 4 +	15 × 6	15 × 6·17	·79	·81	19·34	65	629·26	471·95	377·56
G 4	15 × 6	15 × 6·09	·72	·81	18·15	61	608·2	456·15	364·90
G 4 —	15 × 6	15 × 6·01	·64	·81	16·96	57	587·13	440·35	352·28
G 5 +	15 × 5	15 × 5·26	·70	·80	17·85	60	536·82	426·61	322·10
G 5	15 × 5	15 × 5·16	·60	·80	16·36	55	510·42	382·81	306·25
G 5 —	15 × 5	15 × 5·06	·50	·80	14·88	50	483·75	362·81	290·25
G 6 +	14 × 6	14 × 6·05	·67	·81	18·15	61	532·37	406·77	325·42
G 6	14 × 6	14 × 5·96	·59	·81	16·96	57	511·51	391·97	313·57
G 6 —	14 × 6	14 × 5·87	·5	·81	15·76	53	502·41	376·81	301·45
G 7 +	12 × 6	12 × 6·23	·73	·87	18·45	62	479·13	359·34	287·47

TABLE 124.—ROLLED STEEL JOISTS (*continued*).

Reference Number.	Normal Dimensions. Depth × Width.	Actual Dimensions. Depth × Width.	Thickness of Web.	Mean Thickness of Flanges.	Sectional Area.	Weight per Lineal Foot.	Distributed Load for One Foot Span.		
							Factor 3.	Factor 4.	Factor 5.
No.	Inches.	Inches.	Inch.	Inch.	Sq. Inches.	Pounds.	Tons.	Tons.	Tons.
G 7	12 × 6	12 × 6·11	·61	·87	16·96	57	457·96	343·47	274·78
G 7 —	12 × 6	12 × 5·99	·49	·87	15·47	52	436·8	327·6	262·08
G 8 +	12 × 5	12 × 5·17	·67	·65	13·98	47	339·65	254·74	203·79
G 8	12 × 5	12 × 5·07	·58	·65	12·80	43	322·75	242·06	193·66
G 8 —	12 × 5	12 × 4·98	·48	·65	11·60	39	305·94	229·46	183·56
G 9 +	10 × 6	10 × 6·16	·66	·70	14·27	48	315·10	236·33	189·06
G 9	10 × 6	10 × 6·08	·58	·70	13·54	45·5	306·45	229·84	183·07
G 9 —	10 × 6	10 × 6·01	·51	·70	12·76	43	297·56	223·17	178·54
G 10 +	10 × 5	10 × 5·23	·73	·66	12·34	41·5	270·57	202·93	162·34
G 10	10 × 5	10 × 5·13	·63	·66	11·30	38	258·25	193·68	154·95
G 10 —	10 × 5	10 × 5·03	·52	·66	10·26	34·5	245·92	184·44	147·55
G 11 +	10 × 4½	10 × 4·49	·49	·66	10·11	34	220·92	165·67	132·54
G 11	10 × 4½	10 × 4·41	·41	·66	9·37	31·5	212·01	159·01	127·20
G 11 —	10 × 4½	10 × 4·38	·38	·66	8·63	29	208·22	156·16	124·93
G 12 +	9 × 7	9 × 7·16	·92	·81	18·45	62	358·08	268·56	214·85
G 12	9 × 7	9 × 7·03	·79	·81	17·25	58	345·32	258·99	207·19
G 12 —	9 × 7	9 × 6·90	·66	·81	10·06	54	332·55	249·41	199·53
G 13 +	9 × 3¾	9 × 3·75	·5	·5	7·74	26	140·68	105·51	84·41
G 13	9 × 3¾	9 × 3·69	·44	·5	7·22	24·25	135·11	101·33	81·07
G 13 —	9 × 3¾	9 × 3·63	·38	·5	6·70	22·5	129·63	97·23	77·78

TABLE 124.—ROLLED STEEL JOISTS (*continued*).

Reference Number.	Normal Dimensions. Depth × Width.	Actual Dimensions. Depth × Width.	Thickness of Web.	Mean Thickness of Flanges.	Sectional Area.	Weight per Lineal Foot.	Distributed Load for One Foot Span.		
							Factor 3.	Factor 4.	Factor 5.
No.	Inches.	Inches.	Inch.	Inch.	Sq. Inches.	Pounds.	Tons.	Tons.	Tons.
G 14 +	8 × 6	8 × 6·05	·55	·62	11·3	38	208·61	156·46	125·17
G 14	8 × 6	8 × 5·98	·48	·62	10·71	36	202·92	152·19	121·75
G 14 —	8 × 6	8 × 5·90	·40	·62	10·12	34	197·31	147·98	118·39
G 15 +	8 × 5	8 × 5·12	·56	·62	10·12	34	179·52	134·64	107·71
G 15	8 × 5	8 × 5·01	·45	·62	9·3	31·25	171·71	128·78	103·02
G 15 —	8 × 5	8 × 4·91	·35	·62	8·48	28·5	163·97	122·98	98·38
G 16 +	8 × 4	8 × 4·13	·53	·56	8·33	28	140·32	105·24	84·19
G 16	8 × 4	8 × 4·02	·42	·56	7·44	25	131·86	98·89	79·11
G 16 —	8 × 4	8 × 3·91	·31	·56	6·55	22	123·38	92·53	74·03
G 17 +	7 × 3¾	7 × 3·87	·49	·46	6·55	22	97·14	72·85	58·28
G 17	7 × 3¾	7 × 3·78	·41	·46	5·95	20	91·20	68·40	54·72
G 17 —	7 × 3¾	7 × 3·70	·32	·46	5·36	18	86·20	64·65	51·71
G 18 +	6¼ × 3½	6·25 × 3·57	·45	·5	5·95	20	79·80	59·85	47·88
G 18	6¼ × 3½	6·25 × 3·47	·36	·5	5·36	18	75·35	56·52	45·21
G 18 —	6¼ × 3½	6·25 × 3·38	·26	·5	4·76	16	70·94	53·20	42·56
G 19 +	6 × 5	6 × 5·14	·64	·5	8·33	28	108·19	81·14	64·91
G 19	6 × 5	6 × 5·04	·54	·5	7·73	26	103·93	77·94	62·36
G 19 —	6 × 5	6 × 4·94	·44	·5	7·14	24	99·66	74·74	59·80
G 20 +	6 × 3	6 × 3·09	·39	·5	5·06	17	65·30	48·97	39·18
G 20	6 × 3	6 × 3·04	·34	·5	4·76	16	63·21	47·40	37·92

TABLE 124.—ROLLED STEEL JOISTS (*continued*).

Reference Number.	Normal Dimensions. Depth × Width.	Actual Dimensions. Depth × Width.	Thickness of Web.	Mean Thickness of Flanges.	Sectional Area.	Weight per Lineal Foot.	Distributed Load for One Foot Span.		
							Factor 3.	Factor 4.	Factor 5.
No.	Inches.	Inches.	Inch.	Inch.	Sq. Inches.	Pounds.	Tons.	Tons.	Tons.
G 20 —	6 × 3	6 × 2·99	·29	·5	4·46	15	61·07	45·8	36·66
G 21 +	6 × 2	6 × 2·15	·47	·38	4·16	14	44·07	33·05	26·44
G 21	6 × 2	6 × 2·07	·39	·38	3·65	12·25	40·57	30·43	24·34
G 21 —	6 × 2	6 × 1·99	·31	·38	3·12	10·5	37·07	27·8	22·24
G 22 +	5½ × 2	5·5 × 2·1	·42	·38	3·57	12	36·66	27·49	21·99
G 22	5½ × 2	5·5 × 2·04	·36	·38	3·27	11	34·69	26·01	20·81
G 22 —	5½ × 2	5·5 × 1·99	·31	·38	2·97	10	32·72	24·54	19·63
G 23 +	5 × 5	5 × 5·2	·64	·5625	8·33	28	91·18	68·38	54·71
G 23	5 × 5	5 × 5·05	·49	·5625	7·58	25·5	86·74	65·05	52·04
G 23 —	5 × 5	5 × 4·9	·33	·5625	6·82	23	82·2	61·65	49·32
G 24 +	5 × 4½	5 × 4·62	·62	·58	7·74	26	83·17	62·38	49·90
G 24	5 × 4½	5 × 4·48	·43	·58	7·07	23·75	77·72	58·29	46·63
G 24 —	5 × 4½	5 × 4·35	·35	·58	6·39	21·5	75·20	56·4	45·12
G 25 +	5 × 3	5 × 3·25	·5	·46	5·06	17	51·81	38·86	31·09
G 25	5 × 3	5 × 3·15	·4	·46	4·54	15·25	48·85	36·64	29·31
G 25 —	5 × 3	5 × 3·04	·3	·46	4·02	13·5	45·77	34·33	27·46
G 26 +	4¾ × 1¾	4·75 × 1·82	·42	·35	2·98	10	25·46	19·09	15·27
G 26	4¾ × 1¾	4·75 × 1·77	·37	·35	2·76	9·25	24·20	18·15	14·52
G 26 —	4¾ × 1¾	4·75 × 1·72	·32	·35	2·53	8·5	22·95	17·21	13·77
G 27 +	4⅝ × 3	4·62 × 3·3	·55	·4	4·76	16	44·32	33·24	26·60

TABLE 124.—ROLLED STEEL JOISTS (*continued*).

Reference Number.	Normal Dimensions. Depth × Width.	Actual Dimensions. Depth × Width.	Thickness of Web.	Mean Thickness of Flanges.	Sectional Area.	Weight per Lineal Foot.	Distributed Load for One Foot Span.		
							Factor 3.	Factor 4.	Factor 5.
No.	Inches.	Inches.	Inch.	Inch.	Sq. Inches.	Pounds.	Tons.	Tons.	Tons.
G 27	4⅝ × 3	4·62 × 3·17	·42	·4	4·17	14	41·15	30·79	24·63
G 27 —	4⅝ × 3	4·62 × 3·04	·29	·4	3·57	12	37·78	28·34	22·67
G 28 +	4 × 3	4 × 3·23	·48	·407	4·16	14	34·93	26·2	20·96
G 28	4 × 3	4 × 3·14	·39	·407	3·79	12·75	33·13	24·85	19·88
G 28 —	4 × 3	4 × 3·04	·3	·407	3·42	11·5	31·41	23·55	18·84
G 29 +	4 × 1¾	4 × 1·98	·48	·35	2·97	10	21·57	16·18	12·94
G 29	4 × 1¾	4 × 1·87	·37	·35	2·53	8·5	19·50	14·6	11·70
G 29 —	4 × 1¾	4 × 1·76	·26	·35	2·08	9	17·36	13·02	10·42
G 30 +	3½ × 3	3·5 × 3·14	·45	·30	3·72	12·5	27·64	20·72	16·59
G 30	3½ × 3	3·5 × 2·99	·30	·30	3·20	10·75	25·46	19·1	15·27
G 30 —	3½ × 3	3·5 × 2·84	·15	·30	2·68	9	23·29	17·47	13·98
G 31 +	3½ × 1½	3·5 × 1·68	·37	·30	2·08	7	13·58	10·19	8·15
G 31	3½ × 1½	3·5 × 1·6	·28	·30	1·78	6	12·35	9·26	7·41
G 31 —	3½ × 1½	3·5 × 1·51	·20	·30	1·49	5	11·16	8·37	6·69
G 32 +	3 × 3	3 × 3·16	·47	·40	3·57	12	22·41	16·81	13·45
G 32	3 × 3	3 × 2·99	·30	·40	3·05	10·25	20·56	15·42	12·33
G 32 —	3 × 3	3 × 2·81	·13	·40	2·53	8·5	18·70	14·03	11·22
G 33 +	3 × 1¼	3 × 1·49	·40	·25	1·75	6	9·20	6·9	5·32
G 33	3 × 1¼	3 × 1·4	·31	·25	1·50	5	8·20	6·19	4·95
G 33 —	3 × 1¼	3 × 1·3	·21	·25	1·19	4	7·2	5·40	4·30

TABLE 125.—ROLLED STEEL JOISTS: CALCULATE

(Dorman

Factor o

Reference Number.	Clear Span, or Distance								
	6	8	10	12	14	16	18	20	22
No.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
G 1	...	...	...	...	90·13	78·86	70·10	63·09	57·35
G 2	...	...	..	...	68·15	59·63	53·00	47·70	43·37
G 3	...	...	...	...	46·42	40·61	36·10	32·49	29·54
G 4	...	...	...	...	43·44	38·01	33·79	30·41	27·64
G 5	...	...	...	...	36·45	31·90	28·40	25·52	23·20
G 6	...	...	...	...	37·33	32·66	29·03	26·13	23·75
G 7	...	...	...	38·16	32·71	28·61	25·44	22·39	20·81
G 8	...	...	...	26·88	23·05	20·17	17·93	16·13	14·67
G 9	...	...	30·64	25·54	21·90	19·15	17·02	15·32	13·93
G 10	...	...	25·32	21·52	18·44	16·14	14·34	12·91	11·73
G 11	...	...	21·20	17·66	15·14	13·25	11·77	10·60	9·63
G 12	...	...	34·5	28·75	24·65	21·56	19·17	17·25	15·68
G 13	...	16·9	13·51	11·25	9·65	8·44	7·50	6·75	6·14
G 14	33·82	25·36	20·29	16·91	14·49	12·68	11·27	10·14	9·22
G 15	28·61	21·45	17·17	14·31	12·26	10·73	9·55	8·58	7·8
G 16	21·97	16·48	13·18	10·99	9·42	8·24	7·32	6·59	5·99
G 17	15·20	11·40	9·10	7·60	6·50	5·70	5·08	4·56	4·14
G 18	12·55	9·41	7·53	6·28	5·38	4·70	4·18	3·76	...
G 19	17·32	12·99	10·39	8·66	7·42	6·49	5·77	5·19	...
G 20	10·53	7·90	6·32	5·26	4·51	3·95	3·51	...	...
G 21	6·76	5·07	4·06	3·38	2·90	2·54	2·25	...	...
G 22	5·78	4·30	3·47	2·89	2·48	2·17	...	...	...
G 23	14·46	10·84	8·67	7·23	6·20	...	...	...	...
G 24	12·95	9·72	7·77	6·48	5·55	...	...	...	...
G 25	8·14	6·11	4·89	4·07	3·49	...	...	...	...
G 26	4·03	3·03	2·42	2·02	1·73	...	...	...	...
G 27	6·84	5·13	4·10	3·42	2·93	...	...	...	...
G 28	5·52	4·15	3·31	2·76	2·37	...	...	...	...
G 29	3·25	2·44	1·95	1·62	1·39	...	...	...	...
G 30	4·24	3·18	2·55	2·12	...	...	...	...	...
G 31	2·06	1·54	1·23	1·03	...	...	...	...	...
G 32	3·45	2·57	2 06	1·71	...	...	...	...	...
G 33	1·38	1·03	·825	·688	...	...	...	...	...

Note.—For Dimensions and

SAFE PERMANENT DISTRIBUTED LOADS.

Long, & Co.)

Safety, 1-3rd.

between the Supports, in Feet.									Reference Number.
24	26	28	30	32	34	36	38	40	
Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	No.
52·57	48·53	45·06	42·06	39·43	37·11	35·05	33·20	31·54	G 1
39·75	36·70	34·07	31·80	29·80	28·07	26·50	25·11	...	G 2
27·08	24·99	23·21	21·66	20·30	19·11	18·05	...	...	G 3
25·33	23·40	21·72	20·27	19·00	17·90	...	...	...	G 4
21·26	19·63	18·22	17·01	15·95	15·01	...	...	...	G 5
21·77	20·10	18·66	17·42	16·33	...	...	...	...	G 6
19·08	17·60	16·35	15·26	...	...	...	...	...	G 7
13·44	12·41	11·52	10·75	...	...	...	...	...	G 8
12·77	11·78	10·95	...	...	...	...	...	...	G 9
10·76	9·92	9·22	...	...	...	...	...	...	G 10
8·83	8·15	7·57	...	...	...	...	...	...	G 11
14·38	13·27	12·32	...	...	...	...	...	...	G 12
5·62	5·20	...	...	...	...	...	...	...	G 13
8·45	...	...	...	...	...	...	...	...	G 14
7·15	...	...	...	...	...	...	...	...	G 15
5·5	...	...	...	...	...	...	...	...	G 16
...	...	...	...	...	...	...	...	...	G 17
...	...	...	...	...	...	...	...	...	G 18
...	...	...	...	...	...	...	...	...	G 19
...	...	...	...	...	...	...	...	...	G 20
...	...	...	...	...	...	...	...	...	G 21
...	...	...	...	...	...	...	...	...	G 22
...	...	...	...	...	...	...	...	...	G 23
...	...	...	...	...	...	...	...	...	G 24
...	...	...	...	...	...	...	...	...	G 25
...	...	...	...	...	...	...	...	...	G 26
...	...	...	...	...	...	...	...	...	G 27
...	...	...	...	...	...	...	...	...	G 28
...	...	...	...	...	...	...	...	...	G 29
...	...	...	...	...	...	...	...	...	G 30
...	...	...	...	...	...	...	...	...	G 31
...	...	...	...	...	...	...	...	...	G 32
...	...	...	...	...	...	...	...	...	G 33

Weights of Joists, see Table 124.

TABLE 126.—IRON JOIST GIRDERS: ESTIMATE

(Measure

Factor of

Reference Number.	Sectional Dimensions, Depth × Width.	Weight per Lineal Foot.	Clear Span in Feet, or				
			10	12	14	16	18
No.	Inches.	Pounds.	Tons.	Tons.	Tons.	Tons.	Tons.
1	22½ × 12	245	170·6	142·8	122·0	106·8	94·8
2	20½ × 12	160	112·0	93·2	80·0	70·0	62·1
3	13½ × 8	100	39·6	33·6	29·4	25·2	22·5
4	17 × 14	175	112·0	102·7	79·5	69·3	61·8
5	16 × 14	216	110·0	91·7	78·6	69·0	61·1
6	14 × 12	172	96·0	80·0	68·5	59·8	53·2
7	11⅜ × 12	130	66·0	55·0	47·0	40·6	36·2
8	12½ × 12	110	72·0	56·0	48·0	41·0	37·0
9	10½ × 12	80	39·0	32·4	27·9	24·3	21·6
10	10½ × 16	130	59·0	49·1	41·9	36·5	32·5
11	9¾ × 8	65	25·2	21·0	18·2	15·6	13·5
12	7½ × 9	56	19·7	16·6	14·4	12·1	10·3
13	13 × 12	99	44·0	38·0	31·8	28·2	24·6
14	11 × 9	63	25·0	21·6	18·6	16·7	14·4
15	12½ × 8	57	30·0	24·0	21·7	18·7	16·9
16	10½ × 6	44	18·8	15·2	14·8	12·7	10·0
17	9¾ × 6	35	13·4	12·1	8·8	8·4	7·8
18	8½ × 6	34	10·7	9·1	7·8	6·8	6·1
19	16½ × 5	78	36·8	30·6	26·2	23·0	20·4
20	18½ × 3¾	50	29·4	24·5	21·0	18·2	16·3
21	20 × 5	70	45·4	37·8	32·4	28·4	25·2
22	20½ × 9	84	53·2	43·2	37·2	32·4	28·0
23	24 × 5	88	75·8	63·1	54·1	47·6	42·5
24	16 × 4	46	28·0	23·3	20·0	17·2	15·1
25	16 × 5	67	38·0	31·2	27·1	23·5	21·1
26	14½ × 4½	54	28·4	23·4	20·2	17·8	15·8
27	14 × 3¾	42	19·6	16·5	14·4	12·3	11·1
28	12 × 5	60	23·6	20·0	17·5	15·1	13·4

Safe Permanent Distributed Loads

Brothers & Co.).

Safety, 1-4th.

Distances between Supports.									Reference Number.
20	22	24	26	28	30	32	34	36	
Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	No.
85·4	77·2	71·2	65·7	60·1	56·9	53·4	50·2	47·4	1
55·8	50·6	46·3	42·8	38·8	36·5	35·0	32·8	31·1	2
19·8	18·3	16·8	15·6	14·7	13·5	...	...	...	3
56·0	50·4	46·2	42·6	39·0	36·9	34·0	32·4	30·9	4
55·0	50·0	45·8	42·5	39·3	36·7	34·5	32·5	30·5	5
48·0	42·9	39·6	37·8	34·3	33·1	29·9	28·1	26·6	6
33·0	29·7	27·6	25·4	23·5	21·7	20·3	19·0	18·0	7
34·0	30·0	28·0	26·0	24·0	22·0	20·0	19·0	18·0	8
19·5	17·7	16·2	15·0	13·8	12·9	12·1	11·4	10·8	9
29·5	26·5	24·3	22·5	20·9	19·0	18·4	17·3	16·3	10
12·6	11·4	10·5	9·6	9·0	8·4	7·8	7·5	6·7	11
9·8	7·5	6·8	6·3	5·8	5·5	...	...	...	12
22·4	20·0	18·6	17·1	15·9	14·7	13·1	14·0	12·4	13
13·0	11·8	10·8	10·0	9·0	8·6	8·1	7·6	7·2	14
15·0	13·7	12·0	11·3	10·4	9·8	9·3	...	...	15
9·4	8·3	7·6	7·2	7·0	6·5	...	...	...	16
6·8	6·2	4·6	4·3	4·0	3·2	...	...	...	17
5·5	5·0	4·5	4·2	3·9	3·0	...	...	...	18
18·4	16·7	15·2	14·1	13·2	12·2	11·6	10·8	10·2	19
14·7	13·3	12·3	11·3	10·5	9·8	...	...	...	20
22·7	20·6	18·9	17·5	16·1	15·0	14·1	13·3	12·6	21
26·6	23·6	21·6	20·0	18·4	17·2	...	...	...	22
37·6	34·1	31·5	29·6	27·4	25·2	3·8	22·4	21·0	23
14·0	12·3	11·6	10·5	9·8	8·9	...	...	...	24
19·0	17·2	15·7	14·6	13·5	12·6	11·8	11·1	10·5	25
14·2	12·9	11·7	10·8	10·1	9·5	8·9	...	7·9	26
9·8	8·7	8·0	7·5	7·0	6·6	...	...	...	27
11·9	10·7	10·0	9·3	8·6	8·0	...	...	...	28

FIGS. 33—44.—SECTIONS OF GIRDERS IN TABLE 126.

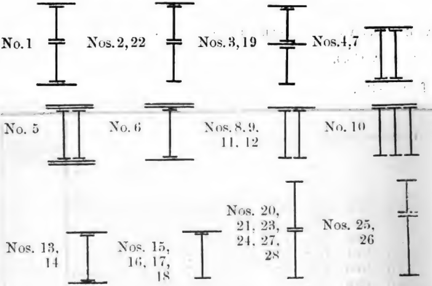

No. 1
Nos. 2, 22
Nos. 3, 19
Nos. 4, 7
No. 5
No. 6
Nos. 8, 9, 11, 12
No. 10
Nos. 13, 14
Nos. 15, 16, 17, 18
Nos. 20, 21, 23, 24, 27, 28
Nos. 25, 26

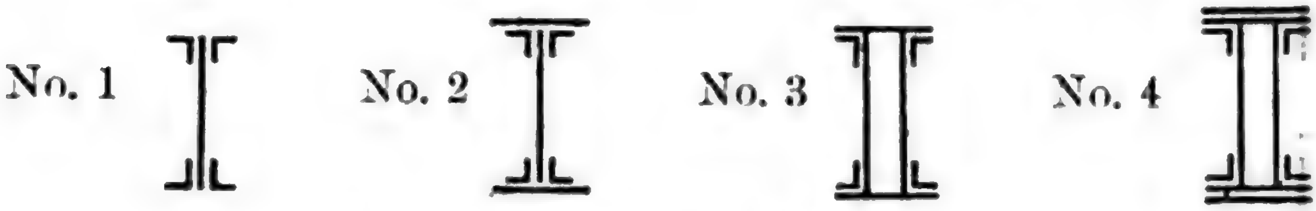
TABLE 127.—ANGLE RIVETTED IRON GIRDERS: ESTIMATED SAFE PERMANENT DISTRIBUTED LOAD.

(Measures Brothers & Co.)

Reference Number.	Sectional Dimensions, Depth × Width.	Weight per Lineal Foot.	Clear Span, or Distance between Supports, in Feet.					
			10	12	14	16	18	20
No.	Inches.	Pounds.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
1	9 × 6⅜	46	13	11	9	8	7	6·5
2	12 × 9	112	...	39	...	29	26	23
3	13 × 16	154	...	59	...	44	...	35
4	20 × 18	224	...	...	...	...	...	88

Reference Number.	Sectional Dimensions, Depth × Width.	Weight per Lineal Foot.	Clear Span, or Distance between Supports, in Feet.						
			22	24	26	30	32	34	36
No.	Inches.	Pounds.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
1	9 × 6⅜	46	...	...	...	...	...	...	...
2	12 × 9	112	21	19	...	...	...	...	...
3	13 × 16	154	...	29	27	...	...	...	...
4	20 × 18	224	...	...	67	58	54	51	49

FIGS. 45—48.—SECTIONS OF GIRDERS IN TABLE 127.



No. 1 No. 2 No. 3 No. 4

TABLE 128.—ANGLES (IRON).
(The Butterley Company.)

Reference Number.	Sum of the Sides.	Sectional Dimensions.	Thickness.	Weight per Lineal Foot.
No.	Inches.	Inches.	Inch.	Pounds.
1	14	7 × 7	¾ to 1¼	26 to 28
2	13½	10 × 3½	7/16 to ⅝	20 to 21¾
3	12½	9 × 3½	7/16 to ⅝	17½ to 23
*4	12½	8 × 4½	7/16 to ⅝	17¾ to 22½
*5	12½	8 × 4½	¾ only.	...
*6	12	6 × 6	⅝ to 1	24 to 27
7	11½	8 × 3½	⅜ to ⅝	16½ to 19
*8	11	5½ × 5½	½ to ¾	19½ to 25¾
*9	10½	7 × 3½	7/16 to ⅝	14¾ to 18½
*10	10½	6½ × 4	½ to ⅝	17 to 23
*11	10	7 × 3	⅜ to ⅝	13 to 16
*12	10	6 × 4	½ to ⅝	16 to 23
*13	10	5 × 5	½ to ¾	17 to 24
*14	9½	6 × 3½	⅜ to ⅝	13½ to 17
*15	9	6 × 3	⅜ to ⅝	12½ to 17
*16	9	5 × 4	⅜ to ⅝	...
*17	9	4½ × 4½	⅜ to ⅝	14½ to 21
*18	8½	5½ × 3	⅜ to ⅝	10¼ to 16½
*19	8½	5 × 3½	⅜ to ⅝	10¼ to 16½
*20	8½	4¼ × 4¼	⅜ to ⅝	10¼ to 16½
*21	8½	4¾ × 3¾	⅜ to ⅝	13½ to 18
*22	8	5 × 3	⅜ to ⅝	9½ to 15½
*23	8	4½ × 3½	⅜ to ⅝	9½ to 18½
*24	8	4 × 4	⅜ to ⅝	9½ to 17
*25	7½	4½ × 3	⅜ to ⅝	9 to 12
*26	7½	4 × 3½	⅜ to ⅝	9 to 14½
*27	7	4 × 3	5/16 to ⅝	8½ to 13½
*28	7	3½ × 3½	⅜ to ⅝	8¼ to 13¼
*29	6½	4 × 2½	5/16 to ⅝	6½ to 11½
*30	6½	3½ × 3	5/16 to ⅝	6½ to 11½
*31	6½	3¼ × 3¼	5/16 to ⅝	6½ to 12¼
*32	6	4 × 2	5/16 to ½	6 to 10½
*33	6	3½ × 2½	5/16 to ½	6 to 10½
*34	6	3 × 3	5/16 to ½	7 to 11½
*35	5½	3 × 2½	¼ to ½	4½ to 8½

TABLE 128.—ANGLES (IRON) (*continued*).

Reference Number.	Sum of the Sides.	Sectional Dimensions.	Thickness.	Weight per Lineal Foot.
No.	Inches.	Inches.	Inch.	Pounds.
*36	$5\frac{1}{2}$	$2\frac{3}{4} \times 2\frac{3}{4}$	$\frac{1}{4}$ to $\frac{1}{2}$	$5\frac{1}{2}$ to $8\frac{1}{2}$
*37	$5\frac{1}{4}$	$2\frac{3}{4} \times 2\frac{1}{2}$	$\frac{1}{4}$ to $\frac{3}{8}$	...
*38	5	3×2	$\frac{1}{4}$ to $\frac{3}{8}$	4 to $7\frac{1}{2}$
*39	5	$2\frac{1}{2} \times 2\frac{1}{2}$	$\frac{1}{4}$ to $\frac{3}{8}$	4 to $7\frac{1}{2}$
*40	$4\frac{3}{4}$	$2\frac{3}{4} \times 2$	$\frac{3}{16}$ to $\frac{3}{8}$	...
*41	$4\frac{1}{2}$	$3 \times 1\frac{1}{2}$	$\frac{3}{4}$ only.	...
*42	$4\frac{1}{2}$	$2\frac{1}{2} \times 2$	$\frac{3}{16}$ to $\frac{3}{8}$	$3\frac{1}{2}$ to 6
*43	$4\frac{1}{2}$	$2\frac{1}{4} \times 2\frac{1}{4}$	$\frac{3}{16}$ to $\frac{3}{8}$	$3\frac{1}{2}$ to $6\frac{3}{4}$
*44	4	2×2	$\frac{3}{16}$ to $\frac{3}{8}$	$2\frac{1}{2}$ to $5\frac{1}{4}$
*45	$3\frac{3}{4}$	$2 \times 1\frac{3}{4}$	$\frac{3}{16}$ to $\frac{3}{8}$	...
*46	$3\frac{1}{2}$	$2 \times 1\frac{1}{2}$	$\frac{3}{16}$ to $\frac{3}{8}$	$2\frac{3}{4}$ to 4
*47	$3\frac{1}{2}$	$1\frac{3}{4} \times 1\frac{3}{4}$	$\frac{3}{16}$ to $\frac{3}{8}$	2 to 4
*48	$3\frac{1}{4}$	$1\frac{3}{4} \times 1\frac{1}{2}$	$\frac{3}{16}$ to $\frac{3}{8}$	$2\frac{3}{4}$ to 4
*49	3	$1\frac{1}{2} \times 1\frac{1}{2}$	$\frac{3}{16}$ to $\frac{3}{8}$	$1\frac{3}{4}$ to $3\frac{1}{4}$
*50	$2\frac{3}{4}$	$1\frac{1}{2} \times 1\frac{1}{4}$	$\frac{3}{16}$ to $\frac{3}{8}$	...
*51	$2\frac{1}{2}$	$1\frac{1}{4} \times 1\frac{1}{4}$	$\frac{1}{8}$ to $\frac{1}{4}$	$1\frac{1}{2}$ to $2\frac{3}{4}$
*52	2	1×1	$\frac{1}{8}$ to $\frac{1}{4}$	1 to $1\frac{1}{4}$
*53	$1\frac{3}{4}$	$\frac{7}{8} \times \frac{7}{8}$	$\frac{1}{8}$ to $\frac{1}{4}$	13 oz.
*54	$1\frac{5}{8}$	$\frac{15}{16} \times \frac{11}{16}$	$\frac{1}{8}$ to $\frac{1}{4}$	...
*55	$1\frac{1}{2}$	$\frac{3}{4} \times \frac{3}{4}$	$\frac{1}{8}$ to $\frac{3}{16}$	12 oz.
*56	$1\frac{1}{4}$	$\frac{5}{8} \times \frac{5}{8}$	$\frac{1}{8}$ to $\frac{3}{16}$	...

* In iron or steel, others in iron only.

TABLE 129.—CHANNELS (IRON).
(The Butterley Company.)

Order Number.	Sectional Dimensions.	Thickness of Web.	Average Thickness of Flanges.	Weight per Lineal Foot.
No.	Inches.	Inch.	Inch.	Pounds.
1	$12 \times 3\frac{3}{4}$	$\frac{11}{16}$	$\frac{5}{8}$	40 to 42
2	$10 \times 3\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	28 to 30
3	8×4	$\frac{1}{2}$	$\frac{1}{2}$	26 to 28
4	$7 \times 2\frac{3}{4}$	$\frac{3}{8}$	$\frac{3}{8}$	...
5	7×2	$\frac{5}{8}$	$\frac{5}{8}$	21 to 23
*6	$6 \times 2\frac{1}{2}$	$\frac{3}{8}$	$\frac{3}{8}$	11 to 14
*7	$6 \times 2\frac{1}{2}$	$\frac{5}{16}$	$\frac{5}{16}$	
8	$5 \times 3\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	18 to 19
*9	$4\frac{1}{2} \times 1\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	11 to 12
*10	$4\frac{1}{2} \times \frac{3}{4}$	$\frac{5}{16}$	$\frac{5}{16}$	6 to $6\frac{1}{2}$
*11	$4 \times \frac{3}{4}$	$\frac{5}{16}$	$\frac{5}{16}$	$5\frac{3}{4}$ to 6
12	$3\frac{1}{2} \times 5$ and $2\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	17 to 18
*13	$2\frac{1}{2} \times 1\frac{1}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	5 to 6

* In iron or steel; others in iron only.

TABLE 130.—TEES (IRON) (The Butterley Company).

Order Number.	Sum of the Flange and Web.	Sectional Dimensions.			Thickness.		Thickness.		Thickness.		Weight per Lineal Foot.
					Flange.	Web.	Flange.	Web.	Flange.	Web.	
No.	Inches.	Ins. (Flange).		Ins. (Web).	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Pounds.
1	20	10	×	10	$1\frac{1}{8}$	$\frac{13}{16}$	$1\frac{1}{8}$	$\frac{7}{8}$	...	...	69 to 70
2	$16\frac{1}{4}$	$6\frac{1}{2}$	×	$9\frac{3}{4}$	$1\frac{5}{8}$	$\frac{3}{4}$	...	...	...	...	57 to 60
3	$14\frac{1}{4}$	$6\frac{1}{4}$	×	8	$\frac{3}{4}$	$\frac{9}{16}$ full	$\frac{3}{4}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{11}{16}$	32 to 34
4	$12\frac{1}{4}$	$6\frac{1}{4}$	×	6	$\frac{3}{4}$	$\frac{9}{16}$	$\frac{3}{4}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{11}{16}$	28 to 30
5	12	6	×	6	$\frac{5}{8}$	$\frac{9}{16}$	...	...	...	...	23 to 25
6	$10\frac{1}{2}$	7	×	$3\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	...	...	...	...	17 to 18
7	*10	6	×	4	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{5}{8}$	...	...	15 to 20
8	*10	5	×	5	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{1}{2}$	$\frac{5}{8}$	16 to 18
9	$*9\frac{3}{8}$	$5\frac{1}{2}$	×	$3\frac{7}{8}$	$\frac{1}{2}$	$\frac{11}{16}$	$\frac{1}{2}$	$\frac{3}{4}$	...	...	18
10	*9	5	×	4	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{9}{16}$	...	...	$14\frac{1}{2}$ to 16
11	*9	6	×	3	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{1}{2}$	...	...	11 to $14\frac{1}{2}$
12	$*8\frac{1}{2}$	$5\frac{1}{2}$	×	3	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{9}{16}$	...	...	$13\frac{1}{4}$
13	$*8\frac{1}{2}$	5	×	$3\frac{1}{2}$	$\frac{1}{2}$	$\frac{3}{4}$	$\frac{1}{2}$	$\frac{13}{16}$	...	...	16
14	*8	4	×	4	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{9}{16}$	...	...	$12\frac{1}{4}$
15	*8	5	×	3	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{1}{2}$	...	...	$9\frac{1}{2}$ to $12\frac{1}{2}$
16	*7	4	×	3	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{1}{2}$	11
17	*7	$3\frac{1}{2}$	×	$3\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{9}{16}$	...	...	11
18	$*6\frac{1}{2}$	$3\frac{1}{2}$	×	3	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{1}{2}$	...	...	$7\frac{3}{4}$ to $10\frac{1}{4}$

* In iron or steel; others in iron only.

TABLE 130.—TEES (IRON) (*continued*).

Order Number.	Sum of the Flange and Web.	Sectional Dimensions.			Thickness.		Thickness.		Thickness.		Weight per Lineal Foot.
					Flange.	Web.	Flange.	Web.	Flange.	Web.	
No.	Inches.	Ins. (Flange).		Ins (Web).	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Pounds.
19	*6½	3	×	3½	½	½	...	...	...	...	10
20	*6	4	×	2	⅜	⅜	7/16	7/16	...	...	7
21	*6	3	×	3	⅜	⅜	½	½	...	...	7
22	*5½	3	×	2½	⅜	⅜	7/16	7/16	½	½	9
23	*5½	2¾	×	2¾	5/16	5/16	⅜	⅜	7/16	7/16	...
24	*5	3	×	2	5/16	5/16	⅜	⅜	...	...	6
25	*5	2½	×	2½	¼	¼	5/16	5/16	⅜	⅜	5¾
26	*4½	2½	×	2	¼	¼	5/16	5/16	⅜	⅜	...
27	*4½	2¼	×	2¼	¼	¼	5/16	5/16	⅜	⅜	5
28	*4¼	2½	×	1¾	¼	¼	5/16	5/16	...	...	3½
29	*4	2	×	2	¼	¼	5/16	5/16	⅜	⅜	3 to 4½
30	*3½	2	×	1½	¼	¼	5/16	5/16	⅜	⅜	...
31	*3½	1¾	×	1¾	3/16	3/16	¼	¼	5/16	5/16	3
32	*3½	1½	×	2	5/16	5/16	...	...	...	...	...
33	*3	1½	×	1½	⅛	⅛	3/16	3/16	¼	¼	2
34	*2½	1¼	×	1¼	⅛	⅛	3/16	3/16	¼	¼	...
35	*2	1	×	1	⅛	⅛	3/16	3/16	¼	¼	·8 to 1·2
36	*1¾	⅞	×	⅞	⅛	⅛	3/16	3/16	¼	¼	...
37	*1½	¾	×	¾	⅛	⅛	3/16	3/16	¼	¼	...

* In iron or steel.

TABLE 131.—BULB BARS (IRON).
(The Butterley Company.)

Order Number.	Width.	Thickness of Bulb.	Thickness of Web.	Weight per Lineal Foot
	Inches.	Inches.	Inch.	Pounds.
1	10	$2\frac{1}{2}$ to $2\frac{5}{8}$	$\frac{1}{2}$ to $\frac{5}{8}$	23
2	6	$3\frac{1}{4}$ to $3\frac{3}{8}$	$\frac{1}{2}$ full to $\frac{5}{8}$ full	21 to 24
3	6	$2\frac{1}{4}$ to $2\frac{3}{8}$	$\frac{1}{2}$ to $\frac{5}{8}$	$13\frac{1}{2}$ to 18

Rolled in iron only.

TABLE 132.—BULB TEES OR DECK BEAMS (IRON).
(The Butterley Company.)

Depth (Web).	Width of Flange.	Width of Bulb.	Minimum Thickness of Web.	Weight per Lineal Foot in Iron.
Inches.	Inches.	Inches.	Inch.	Pounds.
16	$6\frac{1}{4}$	$3\frac{1}{4}$	$\frac{5}{8}$ bare	58 to 62
16	$6\frac{1}{4}$	$2\frac{1}{4}$	$\frac{5}{8}$ bare	53 to 57
15	$6\frac{1}{4}$	$3\frac{1}{4}$	$\frac{5}{8}$ bare	56 to 60
15	$6\frac{1}{4}$	$2\frac{1}{4}$	$\frac{5}{8}$ bare	51 to 55
14	$6\frac{1}{4}$	$3\frac{1}{4}$	$\frac{5}{8}$ bare	54 to 58
14	$6\frac{1}{4}$	$2\frac{1}{4}$	$\frac{5}{8}$ bare	50 to 54
13	$6\frac{1}{4}$	$3\frac{1}{4}$	$\frac{5}{8}$ bare	52 to 56
13	$6\frac{1}{4}$	$2\frac{1}{4}$	$\frac{5}{8}$ bare	48 to 52
12	$6\frac{1}{4}$	$3\frac{1}{4}$	$\frac{5}{8}$ bare	50 to 54
12	$6\frac{1}{4}$	$2\frac{1}{4}$	$\frac{5}{8}$ bare	46 to 50
11	$6\frac{1}{2}$	$2\frac{1}{4}$	$\frac{1}{2}$ bare	45 to 49
†11	6	$2\frac{1}{4}$	$\frac{1}{2}$ bare	36 to 40
10	6	$2\frac{1}{8}$	$\frac{1}{2}$ bare	35 to 39
†10	6	2	$\frac{1}{2}$ bare	32 to 36
†$9\frac{1}{2}$	$5\frac{1}{2}$	$1\frac{3}{4}$	$\frac{1}{2}$ bare	31 to 35
9	$5\frac{1}{2}$	2	$\frac{7}{36}$	32 to 36
9	$6\frac{1}{2}$	2	$\frac{1}{2}$ bare	35 to 39
9	$5\frac{1}{4}$	$1\frac{3}{4}$	$\frac{15}{32}$	29 to 29
$8\frac{1}{2}$	$5\frac{1}{4}$	$1\frac{3}{4}$	$\frac{8}{20}$	25 to 28
8	$6\frac{1}{4}$	$1\frac{3}{4}$	$\frac{9}{16}$ bare	31 to 33
8	$5\frac{1}{4}$	$1\frac{7}{8}$	$\frac{7}{16}$	27 to 30
†8	5	$1\frac{3}{4}$	$\frac{3}{8}$ full	22 to 24
7	5	$1\frac{3}{4}$	$\frac{3}{8}$	23 to 26
†7	5	$1\frac{5}{8}$	$\frac{3}{8}$	19 to 22
6	5	$1\frac{1}{2}$	$\frac{3}{8}$	19 to 22
*6	$4\frac{1}{2}$	$1\frac{9}{16}$	$\frac{3}{8}$	16 to 18
*6	4	$1\frac{1}{2}$	$\frac{7}{16}$	18 to 20
*5	4	$1\frac{1}{2}$	$\frac{3}{8}$	14 to 16
4	3	$1\frac{1}{4}$	$\frac{5}{16}$	9 to 10

* In iron or steel ; † in steel only ; the others in iron only.

TABLE 133.—BULB ANGLES (IRON).

(The Butterley Company.)

Order Number.	Depth (Web).	Width of Flange.	Width of Bulb.	Thickness of Web.	Weight per Lineal Foot.
No.	Inches.	Inches.	Inches.	Inch.	Pounds.
1	12	3½	2¼	½ to ⅝	33 to 38
*2	9	3½	2¼	7/16 to ⅝	24½ to 31
*3	8	2½	1	5/16 to ½	...
*4	7	3¾	1⅛	½ to ⅝	19 to 22
*5	6½	3½	15/16	½ to ⅝	16 to 20
*6	6	2½	⅞	5/16 to ½	...
*7	5	2½	15/16	⅜ to ½	11 to 13

* In iron or steel; other in iron only.

TABLE 134.—SPACE OR Z ANGLES (IRON).

(The Butterley Company.)

Order Number.	Depth of Web.	Width of Flanges.	Thickness.	Weight per Lineal Foot.
No.	Inches.	Inches.	Inch.	Pounds.
1	10	3½ and 3½	7/16 to 9/16	24 to 31
2	9	3 and 3	⅜ to ½	...
3	6	3½ and 3	⅜ to ½	15 to 20
4	5	3 and 2½	½ to ⅝	16 to 20
5	4	3½ and 3	⅜ to 9/16	12½ to 20
6	4	2½ and 2½	⅜ to ½	11 to 14
7	3	3 and 2½	7/16 to ⅝	11 to 15
8	3	2¼ and 2¼	⅜ to ½	9 to 12
9	2⅝	2½ and 2¼	7/16 to ⅝	10 to 14
10	2½	2½ and 2½	⅜ to ½	9 to 12

Can be rolled in iron or steel.

TABLE 135.—Z ANGLES (STEEL).

(Dorman, Long, & Co.)

Depth and Thickness (Web).		Width and Thickness of Flanges.	
Inches.	Inch.	Inches.	Inch.
6	× ⅜, ½, ⅝	3½ and 3	× ⅜, ½, ⅝
5½	× ⅜, ½, ⅝	2¾ and 2¾	× ½, ⅝, ¾
4	× ⅜, ½, ⅝	3 and 2½	× ⅜, ½, ⅝

TABLE 136.—Z ANGLES (STEEL).

(Dorman, Long, & Co.)

Sectional Dimensions.	Thickness.	Sectional Dimensions.	Thickness.	Sectional Dimensions.	Thickness.
EQUAL SIDED.		UNEQUAL SIDED.			
Inches.	Inch.	Inches.	Inch.	Inches.	Inch.
8×8	$\frac{1}{2}, \frac{3}{4}, 1$	10×6	$\frac{9}{16}, \frac{5}{8}, 1$	$5 \times 3\frac{1}{2}$	$\frac{5}{16}, \frac{17}{32}, \frac{3}{4}$
6×6	$\frac{1}{2}, \frac{3}{4}, 1$	$8 \times 4\frac{3}{4}$	$\frac{1}{2}, \frac{3}{4}, 1$	5×3	$\frac{5}{16}, \frac{17}{32}, \frac{3}{4}$
$5\frac{1}{2} \times 5\frac{1}{2}$	$\frac{1}{2}, \frac{3}{4}, 1$	7×4	$\frac{7}{16}, \frac{21}{32}, \frac{7}{8}$	$4\frac{1}{2} \times 4$	$\frac{3}{8}, \frac{5}{8}, \frac{7}{8}$
5×5	$\frac{7}{16}, \frac{5}{8}, \frac{7}{8}$	7×3	$\frac{3}{8}, \frac{9}{16}, \frac{3}{4}$	$4\frac{1}{2} \times 3\frac{1}{2}$	$\frac{3}{8}, \frac{5}{8}, \frac{7}{8}$
$4\frac{3}{4} \times 4\frac{3}{4}$	$\frac{3}{8}, \frac{5}{8}, \frac{7}{8}$	$6\frac{1}{2} \times 4\frac{1}{2}$	$\frac{7}{16}, \frac{11}{16}, 1$	$4\frac{1}{2} \times 3$	$\frac{5}{16}, \frac{17}{32}, \frac{3}{4}$
$4\frac{1}{2} \times 4\frac{1}{2}$	$\frac{3}{8}, \frac{5}{8}, \frac{7}{8}$	$6\frac{1}{2} \times 4$	$\frac{7}{16}, \frac{5}{8}, \frac{13}{16}$	$4 \times 3\frac{1}{2}$	$\frac{3}{8}, \frac{5}{8}, \frac{7}{8}$
4×4	$\frac{5}{16}, \frac{1}{2}, \frac{11}{16}$	$6\frac{1}{2} \times 3$	$\frac{3}{8}, \frac{9}{16}, \frac{3}{4}$	4×3	$\frac{5}{16}, \frac{17}{32}, \frac{3}{4}$
$3\frac{1}{2} \times 3\frac{1}{2}$	$\frac{5}{16}, \frac{1}{2}, \frac{3}{4}$	6×5	$\frac{7}{16}, \frac{11}{16}, 1$	$3\frac{1}{2} \times 3$	$\frac{5}{16}, \frac{1}{2}, \frac{11}{16}$
$3\frac{1}{4} \times 3\frac{1}{4}$	$\frac{5}{16}, \frac{1}{2}, \frac{3}{4}$	6×4	$\frac{3}{8}, \frac{5}{8}, \frac{7}{8}$	$3\frac{1}{2} \times 2\frac{1}{2}$	$\frac{5}{16}, \frac{15}{32}, \frac{5}{8}$
3×3	$\frac{1}{4}, \frac{7}{16}, \frac{11}{16}$	$6 \times 3\frac{1}{2}$	$\frac{3}{8}, \frac{5}{8}, \frac{7}{8}$	$3 \times 2\frac{3}{4}$	$\frac{1}{4}, \frac{15}{32}, \frac{11}{16}$
$2\frac{3}{4} \times 2\frac{3}{4}$	$\frac{1}{4}, \frac{7}{16}, \frac{5}{8}$	6×3	$\frac{3}{8}, \frac{9}{16}, \frac{3}{4}$	$3 \times 2\frac{1}{2}$	$\frac{1}{4}, \frac{7}{16}, \frac{5}{8}$
$2\frac{1}{2} \times 2\frac{1}{2}$	$\frac{1}{4}, \frac{7}{16}, \frac{5}{8}$	$5\frac{1}{2} \times 4$	$\frac{3}{8}, \frac{5}{8}, \frac{7}{8}$	3×2	$\frac{1}{4}, \frac{9}{32}, \frac{9}{16}$
$2\frac{1}{4} \times 2\frac{1}{4}$	$\frac{1}{4}, \frac{3}{8}, \frac{1}{2}$	$5\frac{1}{2} \times 3\frac{1}{2}$	$\frac{3}{8}, \frac{19}{32}, \frac{13}{16}$	$2\frac{1}{2} \times 2$	$\frac{1}{4}, \frac{3}{8}, \frac{1}{2}$
2×2	$\frac{3}{16}, \frac{9}{32}, \frac{3}{8}$	$5\frac{1}{2} \times 3$	$\frac{3}{8}, \frac{9}{16}, \frac{3}{4}$	$2 \times 1\frac{1}{2}$	$\frac{3}{16}, \frac{9}{32}, \frac{3}{8}$
$1\frac{3}{4} \times 1\frac{3}{4}$	$\frac{3}{16}, \frac{9}{32}, \frac{3}{8}$	5×4	$\frac{3}{8}, \frac{19}{32}, \frac{13}{16}$		
$1\frac{1}{2} \times 1\frac{1}{2}$	$\frac{1}{8}, \frac{7}{32}, \frac{5}{16}$				
$1\frac{1}{4} \times 1\frac{1}{4}$	$\frac{1}{8}, \frac{7}{32}, \frac{5}{16}$				
1×1	$\frac{3}{32}, \frac{9}{64}, \frac{1}{4}$				

TABLE 137.—TEES (STEEL).

(Dorman, Long, & Co.)

Width of Flange.	Depth (Web).	Thickness.	Width of Flange.	Depth (Web).	Thickness.
Inches.	Inches.	Inch.	Inches.	Inches.	Inch.
6	3	$\frac{1}{2}$	3	3	$\frac{3}{8}, \frac{1}{2}$
5	3	$\frac{3}{8}, \frac{7}{16}, \frac{1}{2}$	3	$2\frac{1}{2}$	$\frac{3}{8}, \frac{1}{2}$
4	5	$\frac{1}{2}$	$2\frac{1}{2}$	$2\frac{1}{2}$	$\frac{1}{4}, \frac{3}{8}, \frac{1}{2}$
4	4	$\frac{1}{2}$	2	2	$\frac{1}{4}, \frac{5}{16}, \frac{3}{8}$
4	$3\frac{1}{2}$	$\frac{3}{8}, \frac{1}{2}$	2	$1\frac{1}{2}$	$\frac{1}{4}, \frac{5}{16}, \frac{3}{8}$
4	3	$\frac{3}{8}, \frac{1}{2}$	$1\frac{1}{2}$	2	$\frac{1}{4}, \frac{5}{16}$
$3\frac{1}{2}$	$3\frac{1}{2}$	$\frac{3}{8}, \frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$\frac{1}{4}$
$3\frac{1}{2}$	3	$\frac{3}{8}, \frac{1}{2}$			

TABLE 138.—CHANNELS (STEEL).
(Dorman, Long, & Co.)

Reference Number.	Sectional Dimensions.	Thickness.	Sectional Area.	Reference Number.	Sectional Dimensions.	Thickness.	Sectional Area.
No.	Inches.	Inch.	Sq. Ins.	No.	Inches.	Inch.	Sq. Ins.
C 12	$12 \times 3\frac{1}{2}$	$\frac{7}{16}$	6·6	C 6	$6 \times 2\frac{7}{8}$	$\frac{7}{16}$	4·78
C 12	$12 \times 3\frac{1}{2}$	$\frac{9}{16}$	8·1	C 6	$6 \times 2\frac{7}{8}$	$\frac{9}{16}$	5·53
C 11	10×3	$\frac{3}{8}$	5·15	C 5	$5\frac{1}{8} \times 2\frac{7}{8}$	$\frac{7}{16}$	4·85
C 11	10×3	$\frac{1}{2}$	7·1	C 5	$5\frac{1}{8} \times 2\frac{7}{8}$	$\frac{9}{16}$	5·49
C 10	9×3	$\frac{3}{8}$	5·47	C 4	$4\frac{1}{2} \times 2$	$\frac{9}{16}$	4·4
C 10	9×3	$\frac{1}{2}$	6·6	C 4	$4\frac{1}{2} \times 2$	$\frac{11}{16}$	4·96
C 9	$9 \times 2\frac{1}{2}$	$\frac{3}{8}$	5·23	C 3	$4\frac{1}{2} \times 1\frac{3}{4}$	$\frac{7}{16}$	3·13
C 9	$9 \times 2\frac{1}{2}$	$\frac{1}{2}$	6·36	C 3	$4\frac{1}{2} \times 1\frac{3}{4}$	$\frac{9}{16}$	3·75
C 8	7×3	$\frac{3}{8}$	4·83	C 2	4×3	$\frac{3}{8}$	5·0
C 8	7×3	$\frac{1}{2}$	5·71	C 2	4×3	$\frac{1}{2}$	5·5
C 7	$6 \times 3\frac{7}{8}$	$\frac{1}{2}$	7·0	C 1	$3\frac{1}{2} \times 1\frac{1}{2}$	$\frac{3}{8}$	3·9
C 7	$6 \times 3\frac{7}{8}$	$\frac{5}{8}$	7·8	C 1	$3\frac{1}{2} \times 1\frac{1}{2}$	$\frac{1}{2}$	2·92

TABLE 139.—BULB BARS (STEEL).
(Dorman, Long, & Co.)

Length.	Thickness.	Length.	Thickness.	Length.	Thickness.
Inches.	Inch.	Inches.	Inch.	Inches.	Inch.
12	$\frac{7}{16}, \frac{5}{8}, \frac{3}{4}$	9	$\frac{7}{16}, \frac{17}{32}, \frac{5}{8}$	$7\frac{1}{2}$	$1\frac{1}{2}$
11	$\frac{7}{16}, \frac{17}{32}, \frac{5}{8}$	$8\frac{1}{2}$	$\frac{7}{16}, \frac{17}{32}, \frac{5}{8}$	$7\frac{1}{2}$	$\frac{3}{8}, \frac{1}{2}, \frac{5}{8}$
$10\frac{1}{2}$	$\frac{7}{16}, \frac{17}{32}, \frac{5}{8}$	8	$\frac{7}{16}, \frac{17}{32}, \frac{5}{8}$	7	$\frac{3}{8}, \frac{1}{2}, \frac{5}{8}$
10	$\frac{7}{16}, \frac{17}{32}, \frac{5}{8}$	8	$\frac{1}{2}, \frac{5}{8}, \frac{3}{4}$	$6\frac{1}{2}$	$\frac{5}{16}, \frac{13}{32}, \frac{1}{2}$
$9\frac{1}{2}$	$\frac{7}{16}, \frac{17}{32}, \frac{5}{8}$	$7\frac{1}{2}$	$1\frac{1}{8}$	6	$\frac{5}{16}, \frac{13}{32}, \frac{1}{2}$

TABLE 140.—BULB ANGLES (STEEL).
(Dorman, Long, & Co.)

Depth (Web).	Width of Flange.	Thickness.	Depth (Web).	Width of Flange.	Thickness.
Inches.	Inches.	Inch.	Inches.	Inches.	Inch.
8	3	$\frac{7}{16}, \frac{9}{16}, \frac{11}{16}$	6	3	$\frac{3}{8}, \frac{1}{2}, \frac{5}{8}$
$7\frac{1}{2}$	3	$\frac{7}{16}, \frac{9}{16}, \frac{11}{16}$	$5\frac{1}{2}$	3	$\frac{9}{16}, \frac{15}{32}, \frac{3}{8}$
7	3	$\frac{7}{16}, \frac{9}{16}, \frac{11}{16}$	3	$1\frac{3}{4}$	$\frac{1}{2}, \frac{13}{32}, \frac{5}{16}$
$6\frac{1}{2}$	3	$\frac{7}{16}, \frac{9}{16}, \frac{11}{16}$	$2\frac{3}{4}$	$1\frac{3}{4}$	$\frac{1}{4}, \frac{7}{16}$
6	$3\frac{1}{2}$	$\frac{7}{16}, \frac{9}{16}, \frac{11}{16}$	$2\frac{1}{4}$	$1\frac{3}{4}$	$\frac{1}{4}, \frac{11}{32}, \frac{7}{16}$

TABLE 141.—STEEL GIRDERS.

(Dorman, Long, & Co.)

Reference Number.	Normal Dimensions. Depth × Width.	Compounded of Joists and Plates.		Sectional Area.	Weight per Lineal Foot.	Distributed Load for One Foot Span.		
						Factor 3.	Factor 4.	Factor 5.
No.	Inches.	Joists.	Plates.	Sq. Ins.	Pounds.	Tons.	Tons.	Tons.
G 8 C 1	$12\frac{3}{8}$ × 8	1 G 8 and	1 plate $\frac{3}{8}$ in.	15·8	57	362·09	271·57	217·25
G 8 C 2	$12\frac{3}{8}$ × 12	2 G 8 ,,	1 ,, $\frac{3}{8}$,,	30·1	105	709·76	532·32	425·85
G 8 C 3	$12\frac{3}{8}$ × 16	3 G 8 ,,	1 ,, $\frac{3}{8}$,,	44·4	157	1057·21	792·91	634·32
G 8 C 4	13 × 10	1 G 8 ,,	2 ,, $\frac{1}{2}$,,	22·8	86	686·60	511·95	411·96
G 8 C 5	13 × 12	2 G 8 ,,	2 ,, $\frac{1}{2}$,,	37·6	136	1071·15	802·53	642·70
G 8 C 6	13 × 16	3 G 8 ,,	2 ,, $\frac{1}{2}$,,	54·4	209	1500·09	1125·16	900·53
G 8 C 7	13 × 10	1 G 8 ,,	4 ,, $\frac{1}{2}$,,	32·8	120	1076·02	645·61	807·02
G 8 C 8	14 × 12	2 G 8 ,,	4 ,, $\frac{1}{2}$,,	49·6	176	1524·69	1143·52	914·90
G 8 C 9	14 × 16	3 G 8 ,,	4 ,, $\frac{1}{2}$,,	70·4	269	2084·65	1563·48	1250·89
G 8 C 10	24 × 5	2 G 8		...	...	...	...	...
G 8 C 11	$24\frac{1}{2}$ × 8	2 G 8 and	1 plate $\frac{1}{2}$ in.	...	...	...	...	...
G 8 C 12	25 × 10	2 G 8 ,,	2 ,, $\frac{1}{2}$,,	...	...	...	...	...

TABLE 143.—WHITWORTH SCREW BOLTS, ETC. (*continued*).

Screw.			Head and Nut, Hexagonal.		
Diameter of Bolt and Screw.	Diameter at Bottom of Thread.	Threads per Inch.	Thickness of Head.	Thickness of Nut.	Breadth across the Flats.
Inches.	Inches.	Threads.	Inches.	Inches.	Inches.
4	...	3	...	...	...
4¼	...	2⅞	...	...	...
4½	...	2⅞	...	...	...
4¾	...	2¾	...	...	...
5	...	2¾	...	...	...
5¼	...	2⅝	...	...	...
5½	...	2⅝	...	...	...
5¾	...	2½	...	...	...
6	...	2½	...	...	...

TABLE 144.—SELLERS OR FRANKLIN INSTITUTE STANDARD SCREW BOLTS AND NUTS.

Threads triangular in section; heads and nuts hexagonal.

Diameter of Bolt and Screw.	Diameter at Bottom of Thread.	Width of Flat Summits and Base of Thread.	Threads per Inch.	Diameter of Bolt and Screw.	Diameter at Bottom of Thread.	Width of Flat Summits and Base of Thread.	Threads per Inch.
Inches.	Inches.	Inch.	Thre'ds.	Inches.	Inches.	Inch.	Thre'ds.
¼	·185	·0062	20	2	1·712	·0277	4½
5/16	·240	·0074	18	2¼	1·962	·0277	4½
⅜	·294	·0078	16	2½	2·176	·0312	4
7/16	·344	·0089	14	2¾	2·426	·0312	4
½	·400	·0096	13	3	2·629	·0357	3½
9/16	·454	·0104	12	3¼	2·879	·0357	3½
⅝	·507	·0113	11	3½	3·100	·0384	3¼
¾	·620	·0125	10	3¾	3·317	·0413	3
⅞	·731	·0138	9	4	3·567	·0413	3
1	·837	·0156	8	4¼	3·798	·0435	2⅞
1⅛	·940	·0178	7	4½	4·028	·0454	2¾
1¼	1·065	·0178	7	4¾	4·256	·0476	2⅝
1⅜	1·160	·0208	6	5	4·480	·0500	2½
1½	1·284	·0208	6	5¼	4·730	·0500	2½
1⅝	1·389	·0227	5½	5½	4·953	·0526	2⅜
1¾	1·491	·0250	5	5¾	5·203	·0526	2⅜
1⅞	1·616	·0250	5	6	5·423	·0555	2¼

Note 1.—The breadth of heads and nuts, across the flats, is equal to 1½ diameters + 1/16 inch.

Note 2.—The thicknesses of the head and the nut are equal to 1 diameter − 1/16 inch.

TABLE 145.—WHITWORTH'S STANDARD PITCHES OF THREAD FOR SCREWED IRON PIPING.

Diameter.	Threads per Inch.	Diameter.	Threads per Inch.	Diameter.	Threads per Inch.
Inches.	Threads.	Inches.	Threads.	Inches.	Threads.
⅛	28	⅝	14	1½	11
¼	19	¾	14	1¾	11
⅜	19	1	11	2	11
½	14	1¼	11	above 2	11

TABLE 146.—FRENCH STANDARD BOLTS AND NUTS WITH HEXAGONAL HEADS AND NUTS.

(Armengaud).

1. TRIANGULAR THREAD (Equilateral Triangle).

Screw.				Head and Nut.			
Diameter of Bolt and Screw.		Diameter at Bottom of Thread.	Number of Threads per Inch.	Thickness of Head.	Thickness of Nut.	Breadth across the Flats.	Working Tensile Stress.
Millimetres.	Inches.	Inches.	Threads.	Inches.	Inches.	Inches.	Lbs.
5	·20	·13	18·1	·24	·20	·55	44
7·5	·30	·22	16	·30	·30	·68	99
10	·39	·31	14·1	·38	·39	·88	178
12·5	·49	·39	12·7	·44	·49	1·04	277
15	·59	·48	11·5	·52	·59	1·20	400
17·5	·69	·58	10·6	·58	·69	1·40	545
20	·79	·66	9·8	·66	·79	1·50	713
22·5	·89	·76	9·1	·72	·89	1·68	902
							Tons.
25	·98	·84	8·5	·80	·98	1·84	·50
30	1·18	1·02	7·5	·94	1·18	2·16	·73
35	1·38	1·20	6·7	1·08	1·38	2·48	·99
40	1·58	1·40	6·0	1·22	1·58	2·80	1·30
45	1·77	1·56	5·5	1·36	1·77	3·20	1·64
50	1·97	1·74	5·1	1·50	1·97	3·44	2·03
55	2·17	1·92	4·7	1·64	2·17	3·76	2·45
60	2·36	2·08	4·4	1·74	2·36	4·08	2·92
65	2·56	2·26	4·1	1·92	2·56	4·40	3·42
70	2·76	2·44	3·8	2·06	2·76	4·70	3·97
75	2·95	2·60	3·5	2·20	2·95	5·00	4·56
80	3·15	2·78	3·4	2·34	3·15	5·35	5·12

TABLE 146.—FRENCH STANDARD BOLTS AND NUTS (*con.*).

2. SQUARE THREAD.

Screw.				Head and Nut.			Working Tensile Stress.
Diameter of Bolt and Screw.		Depth of Thread.	Number of Threads per Inch.	Thickness of Head.	Thickness of Nut.	Breadth across the Flats.	
Millimetres.	Inches.	Inches.	Threads.	Inches.	Inches.	Inches.	Tons.
20	·79	·072	6·57	...	1·82	...	·32
25	·98	·081	5·97	...	2·01	...	·51
30	1·18	·093	5·40	...	2·22	...	·73
35	1·38	·10	4·93	...	2·41	...	·99
40	1·57	·106	4·53	...	2·63	...	1·30
45	1·77	·114	4·20	...	2·85	...	1·64
50	1·97	·128	3·91	...	3·07	...	2·03
55	2·17	·13	3·65	...	3·30	...	2·45
60	2·36	·14	3·43	...	3·50	...	2·92
65	2·56	·15	3·23	...	3·70	...	3·42
70	2·76	·158	3·06	...	3·92	...	3·97
75	2·95	·166	2·92	...	4·13	...	4·56
80	3·15	·174	2·76	...	4·36	...	5·18
85	3·35	·183	2·63	...	4·58	...	5·85
90	3·54	·192	2·51	...	4·78	...	6·56
95	3·74	·200	2·41	...	5·00	...	7·30
100	3·94	·209	2·31	...	5·22	...	8·10
105	4·13	·220	2·22	...	5·43	...	8·93
110	4·33	·226	2·13	...	5·66	...	9·80
115	4·53	·230	2·06	...	5·87	...	10·71
120	4·72	·234	2·00	...	6·08	...	11·66

TABLE 147.—IRON WASHERS.

Diameters.		Thickness.	Number per Pound.	Diameters.		Thickness.	Number per Pound.
Washer.	Bolt Hole.			Washer.	Bolt Hole.		
Inches.	Inches.	B.W.G.	Washers.	Inches.	Inches.	B.W.G.	Washers.
$\frac{1}{2}$	$\frac{1}{4}$	18	543	$1\frac{3}{4}$	$\frac{11}{16}$	10	17·0
$\frac{5}{8}$	$\frac{5}{16}$	16	228	2	$\frac{13}{16}$	10	10·7
$\frac{3}{4}$	$\frac{5}{16}$	16	147	$2\frac{1}{4}$	$\frac{15}{16}$	9	8·7
$\frac{7}{8}$	$\frac{3}{8}$	16	123	$2\frac{1}{2}$	$1\frac{1}{16}$	9	6·3
1	$\frac{7}{16}$	14	70·0	$2\frac{3}{4}$	$1\frac{1}{4}$	9	4·7
$1\frac{1}{4}$	$\frac{1}{2}$	14	50·0	3	$1\frac{3}{8}$	9	3·7
$1\frac{3}{8}$	$\frac{9}{16}$	12	30·0	$3\frac{1}{2}$	$1\frac{1}{2}$	9	3·0
$1\frac{1}{2}$	$\frac{5}{8}$	12	25·7				

Table 148.—Weights of 100 Hexagonal Head Bolts and Nuts.

Length under Head.	Diameter of Bolts.						
	¼ in.	⅜ in.	½ in.	⅝ in.	¾ in.	⅞ in.	1 in.
Inches.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
1	3⅛	7¾	16⅜	26¾	...	...	...
1¼	3½	8⅝	17⅜	29¼	...	...	...
1½	3⅞	9½	18⅜	31¾	...	...	...
1¾	4¼	10⅜	19⅜	34¼	...	...	...
2	4⅝	11¼	20⅜	36¾	58	115	159
2¼	5	12¼	21⅞	39¼	61½	117½	164
2½	5⅜	13⅛	23⅜	41¾	65	120	169
2¾	5¾	14	24⅞	44¼	68½	122½	174
3	6⅛	15	26⅜	46¾	72	125	179
3½	6¾	16⅞	29⅜	51¼	78	133	189
4	7⅜	18⅞	32⅜	55¾	84	141	199
4½	8	20⅜	35⅜	60¼	89½	149	209
5	8⅝	22	38⅜	64¾	95	157	219
5½	9⅜	23⅝	41⅜	68¾	100½	165	230
6	10	25¼	44⅜	72¾	106	173	241
7	11⅜	28¼	50⅜	80¾	118	189	263
8	12¾	31¾	56⅜	88¾	131	205	285
9	14⅛	34¾	62⅜	96¾	144	221	307
10	15⅝	38¾	68⅜	104¾	158	237	329
11	16⅞	41⅜	74⅜	112⅞	173	253	351
12	18¼	44¾	80⅜	121½	188	269	372

Table 149.—Weights of 100 square-head Bolts and Nuts.

Length under Head.	Diameter of Bolts.						
	¼ in.	⅜ in.	½ in.	⅝ in.	¾ in.	⅞ in.	1 in.
Inches.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
1	3½	9	20	32	...	...	...
1¼	3⅞	9⅞	21	34½	...	...	...
1½	4¼	10¾	22	37	...	...	...
1¾	4⅝	11⅝	23	39½	...	...	...
2	5	12½	24	42	70	130	180
2¼	5⅜	13½	25½	44½	73½	132½	185
2½	5¾	14⅜	27	47	77	135	190

TABLE 149.—WEIGHT OF 100 SQUARE-HEAD BOLTS AND NUTS (*continued*).

Length under Head.	Diameter of Bolts.						
	$\frac{1}{4}$ in.	$\frac{3}{8}$ in.	$\frac{1}{2}$ in.	$\frac{5}{8}$ in.	$\frac{3}{4}$ in.	$\frac{7}{8}$ in.	1 in.
Inches.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
$2\frac{3}{4}$	$6\frac{1}{8}$	$15\frac{1}{2}$	$28\frac{1}{2}$	$49\frac{1}{2}$	$80\frac{1}{2}$	$137\frac{1}{2}$	195
3	$6\frac{1}{2}$	$16\frac{1}{4}$	30	52	84	140	200
$3\frac{1}{2}$	$7\frac{1}{8}$	$18\frac{1}{8}$	33	$56\frac{1}{2}$	90	148	210
4	$7\frac{3}{4}$	20	36	61	96	156	220
$4\frac{1}{2}$	$8\frac{3}{8}$	$21\frac{5}{8}$	39	$65\frac{1}{2}$	$101\frac{1}{2}$	164	230
5	9	$23\frac{1}{4}$	42	70	107	172	240
$5\frac{1}{2}$	$9\frac{3}{4}$	$24\frac{7}{8}$	45	74	$112\frac{1}{2}$	180	251
6	$10\frac{3}{8}$	$26\frac{1}{2}$	48	78	118	188	262
7	$11\frac{3}{4}$	$29\frac{1}{2}$	54	86	130	204	284
8	$13\frac{1}{8}$	33	60	94	143	220	306
9	$14\frac{1}{2}$	36	66	102	156	236	328
10	16	40	72	110	170	252	350
11	$17\frac{1}{4}$	43	78	118	185	268	372
12	$18\frac{5}{8}$	46	84	127	200	284	393

TABLE 150.—WEIGHT AND TENSILE STRENGTH OF ORDINARY IRON BOLTS.

(Chapman.)

Ends Enlarged, or Upset.				Ends not Enlarged.	
Diameter of Shank.	Weight per Lineal Foot.	Breaking Stress.	Breaking Stress.	Diameter of Shank.	Weight per Lineal Foot.
Inches.	Pounds.	Tons.	Pounds.	Inches.	Pounds.
$\frac{1}{8}$	·0414	·245	549	...	...
$\frac{3}{16}$	·093	·553	1,239	...	...
$\frac{1}{4}$	·165	·983	2,202	·35	·321
$\frac{5}{16}$	·258	1·53	3,427	·43	·452
$\frac{3}{8}$	·372	2·21	4,950	·50	·654
$\frac{7}{16}$	·506	3·00	6,720	·58	·897
$\frac{1}{2}$	·651	3·93	8,803	·66	1·14
$\frac{9}{16}$	·837	4·97	11,133	·73	1·41
$\frac{5}{8}$	1·03	6·14	13,754	·80	1·67
$\frac{11}{16}$	1·25	7·42	16,621	·88	2·03
$\frac{3}{4}$	1·49	8·83	19,779	·96	2·41
$\frac{13}{16}$	1·75	10·4	23,296	1·04	2·81

TABLE 150.—WEIGHT AND STRENGTH OF IRON BOLTS (*con.*)

Ends Enlarged, or Upset.				Ends not Enlarged.	
Diameter of Shank.	Weight per Lineal Foot.	Breaking Stress.	Breaking Stress.	Diameter of Shank.	Weight per Lineal Foot.
Inches.	Pounds.	Tons.	Pounds.	Inches.	Pounds.
$\frac{7}{8}$	2·03	12·0	26,880	1·12	3·26
$\frac{15}{16}$	2·33	13·8	30,012	1·20	3·77
1	2·65	15·7	35,168	1·27	4·27
$1\frac{1}{16}$	2·99	16·8	37,632	1·35	4·77
$1\frac{1}{8}$	3·35	18·9	42,336	1·42	5·28
$1\frac{3}{16}$	3·73	21·1	47,264	1·49	5·81
$1\frac{1}{4}$	4·13	23·3	52,192	1·55	6·39
$1\frac{5}{16}$	4·56	25·7	57,568	1·64	7·04
$1\frac{3}{8}$	5·00	28·2	63,168	1·72	7·74
$1\frac{7}{16}$	5·47	30·8	68,992	1·80	8·48
$1\frac{1}{2}$	5·95	33·6	75,264	1·87	9·20
$1\frac{9}{16}$	6·46	36·4	81,536	1·94	9·88
$1\frac{5}{8}$	6·99	39·4	88,256	2·00	10·6
$1\frac{11}{16}$	7·53	42·5	95,200	2·07	11·3
$1\frac{3}{4}$	8·10	45·7	102,368	2·14	12·0
$1\frac{13}{16}$	8·69	49·0	109,760	2·22	12·9
$1\frac{7}{8}$	9·30	52·5	117,600	2·30	13·8
$1\frac{15}{16}$	9·93	56·0	125,440	2·38	14·7
2	10·6	59·7	133,728	2·45	15·7
$2\frac{1}{8}$	12·0	63·8	142,912	2·59	17·5
$2\frac{1}{4}$	13·4	71·6	160,384	2·73	19·5
$2\frac{3}{8}$	14·9	79·7	178,528	2·88	21·6
$2\frac{1}{2}$	16·5	88·4	198,016	3·02	23·9
$2\frac{5}{8}$	18·2	97·4	218,176	3·16	26·1
$2\frac{3}{4}$	20·0	106·9	239,456	3·30	28·5
$2\frac{7}{8}$	21·9	116·8	261,632	3·45	31·1
3	23·8	127·2	284,928	3·60	33·9
$3\frac{1}{4}$	27·9	141·0	315,840	3·86	39·1
$3\frac{1}{2}$	32·4	163·6	366,464	4·12	44·4
$3\frac{3}{4}$	37·2	187·7	420,448	4·41	51·0
4	42·3	213·6	478,464	4·70	57·8
$4\frac{1}{4}$	47·8	227·0	508,480	4·98	65·2
$4\frac{1}{2}$	53·6	254·5	570,080	5·25	72·9
$4\frac{3}{4}$	59·7	283·5	635,040	5·53	80·5
5	66·1	314·2	703,808	5·80	88·1
$5\frac{1}{4}$	72·9	324·7	727,328	6·08	97·0
$5\frac{1}{2}$	80·0	356·4	798,336	6·36	106
$5\frac{3}{4}$	87·5	389·5	872,480	6·63	116
6	95·2	424·1	949,984	6·90	126

TABLE 151.—NAILS, IRON OR STEEL: SIZES AND WEIGHTS.

Description.	Length.	Weight per 1,000.		Description.	Length.	Weight per 1,000.	
	In.	Lb.	Oz.		In.	Lb.	Oz.
Spike, die heads, flat points, wrought . .	1½	4	0	Clasp, fine, wrought	3	11	0
	2	7	4	,,	4	...	
	2½	12	8	Clasp, fine, cut . .	2	6	0
,,	3	19	12	,,	2½	10	0
,,	3½	27	4	,,	3	16	0
,,	4	42	8	Clasp, strong . .	1¾	7	0
,,	5	89	8	,, . .	2¼	10	0
,,	6	153	12	,, . .	2½	12	0
,,	7	241	0	,, . .	2¾	14	0
Spike, square head, flat points, wrought	6	263	0	,, . .	3⅛	20	0
	7	361	12	,, . .	3⅜	25	0
	8	478	12	,, . .	3¾	32	0
,,	9	596	0	,, . .	4	40	0
,,	10	707	8	Clout, countersunk, fine, wrought . .	1	4	12
,,	12	998	0		1½	9	0
Rose, sharp points, wrought	1	2	9		2	19	0
				,,	3	44	0
Rose, fine flat points, wrought	1¼	5	0	Clout, countersunk, strong, wrought . .	1½	14	8
	1½	4	0		2	25	8
,,	2	7	12		2½	43	8
Rose, fine flat points, strong .	2½	18	8	,,	3½	82	0
	3	28	12	Clout, strong, wrought . .	¾	2	0
,,	3½	40	0		1	3	0
,,	4	54	4	,,	1¼	5	0
,,	4½	74	8	,,	1½	7	0
,,	5	92	8	,,	2	13	0
Rose, fine flat points, stamped	1¼	4	0	Brads, fine, billed, wrought . .	½	0	4
	1½	5	0		¾	0	10
,,	2	7	0	,,	1	1	0
,,	2½	11	0	,,	1¼	1	8
,,	3	25	0	,,	1½	2	8
Clasp, bastard, wrought . .	2	7	0	,,	1¾	3	0
	2½	12	0	,,	2	4	0
Clasp, fine, wrought	1	1	8	Brads, fine, billed, cut . . .	½	0	3¾
,,	1¼	2	0		¾	0	7¾
,,	1½	3	0	,,	1	1	0
,,	1¾	4	0	,,	1¼	1	8
,,	2	5	0	,,	1½	2	0
,,	2½	7	0	,,	2	3	4

TABLE 151.—NAILS, IRON OR STEEL: SIZES AND WEIGHTS (*continued*).

Description.	Length.	Weight per 1,000.	
	In.	Lb.	Oz.
Brads, flooring, cut	2¼	10	0
"	2½	15	0
"	3¼	20	0
Brads, moulder's, fine, cut	3½	10	8
	4	12	13
"	4½	15	4
"	5	17	10
Tacks, flat head, wrought	⅜	0	5
	½	0	8
"	⅝	0	14
Tacks, round head, wrought	⅝	1	4
Tacks, tinned, flat head, wrought	⅜	0	5½
	½	0	9
"	⅝	0	15½
Tacks, moulding, wrought	2½	19	12
	3	32	4
"	4	54	0
Tacks, flat head, cut	⅜	0	5¾
	½	0	8¼
"	⅝	0	12
Cooper's flat, wrought	¾	1	8
	1	2	4
"	1¼	3	4
Dog, countersunk, wrought	2	21	4
	2½	27	12
"	3	39	8
Tenter hooks	1½	6	0
Mop, caulker's, wrought	4½	62	0
	7	125	0
Slating, wrought, galvanised	2	...	
Scupper, wrought	¾	4	0
"	1	6	4
"	1¼	10	4
Roofing rivets, wrought with burrs, galvanised, ¼ in. diam.	½	...	
	⅜	...	
Glaziers' sprigs	½	0	4
"	¾	0	14
Horse shoe	2	5	8
"	2⅛	7	0
"	2¼	8	8
"	2⅜	10	0
"	2½	11	0
"	2¾	13	8
Cart wheel tyre	3½	187	8
"	4	218	12

TABLE 152.—GALVANISED WROUGHT IRON CYLINDRICAL CISTERNS.

(Gospel Oak Company.)

Capacity (about)	Diameter.	Height.	Capacity (about)	Diameter.	Height.
Gallons.	Inches.	Inches.	Gallons.	Inches.	Inches.
5	11	17½	40	21	33
10	14	21	50	23	35
15	16	22	60	25	36
20	18	24	80	27	42
30	19½	30	100	28	48

TABLE 154.—CAST IRON CYLINDERS (*continued*).

Inside Diam.	Thickness in Inches.										
	⅝	¾	⅞	1	1⅛	1¼	1⅜	1½	1¾	2	2¼
Inch.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.
48	2·66	3·21	3·75	4·30	4·85	5·40	5·96	6·52	7·63	8·77	9·91
51	2·82	3·40	3·98	4·56	5·14	5·73	6·32	6·91	8·09	9·29	10·5
54	2·99	3·60	4·21	4·82	5·44	6·06	6·69	7·31	8·55	9·82	11·1
57	3·15	3·80	4·44	5·09	5·73	6·38	7·05	7·70	9·01	10·4	11·7
60	3·32	4·00	4·67	5·35	6·03	6·71	7·41	8·10	9·47	10·9	12·3
63	3·48	4·19	4·90	5·61	6·33	7·04	7·78	8·49	9·93	11·4	12·9
66	3·64	4·39	5·13	5·88	6·62	7·37	8·14	8·89	10·4	11·9	13·5
69	3·81	4·59	5·36	6·14	6·92	7·70	8·51	9·28	10·9	12·5	14·1
72	3·97	4·78	5·59	6·40	7·21	8·03	8·87	9·67	11·3	13·0	14·7
75	4·14	4·98	5·82	6·66	7·51	8·36	9·24	10·1	11·8	13·5	15·2
78	4·30	5·18	6·05	6·93	7·81	8·69	9·60	10·5	12·2	14·0	15·8
81	4·46	5·38	6·28	7·19	8·10	9·02	9·97	10·9	12·7	14·6	16·4
84	4·63	5·57	6·51	7·45	8·40	9·35	10·3	11·3	13·2	15·1	17·0
87	4·79	5·77	6·74	7·72	8·69	9·67	10·7	11·6	13·6	15·6	17·6
90	4·96	5·97	6·97	7·98	8·99	10·0	11·1	12·0	14·1	16·1	18·2
93	5·12	6·17	7·20	8·24	9·29	10·3	11·4	12·4	14·5	16·7	18·8
96	5·28	6·36	7·43	8·51	9·58	10·7	11·8	12·8	15·0	17·2	19·4
99	5·45	6·56	7·66	8·77	9·88	11·0	12·2	13·2	15·5	17·7	20·0
102	5·61	6·76	7·89	9·03	10·2	11·3	12·5	13·6	15·9	18·2	20·6
105	5·78	6·95	8·12	9·29	10·5	11·7	12·9	14·0	16·4	18·8	21·2
108	5·94	7·15	8·36	9·56	10·8	12·0	13·3	14·4	16·8	19·3	21·8
111	6·10	7·35	8·59	9·82	11·1	12·3	13·6	14·8	17·3	19·8	22·3
114	6·27	7·55	8·82	10·1	11·4	12·6	14·0	15·2	17·8	20·3	22·9
117	6·43	7·74	9·05	10·4	11·7	13·0	14·3	15·6	18·2	20·9	23·5
120	6·59	7·94	9·28	10·6	12·0	13·3	14·7	16·0	18·7	21·4	24·1

TABLE 156.—CAST-IRON CYLINDERS : WEIGHT BY EXTERNAL DIAMETER.

Length, 1 Foot.

External Diameter.	Thickness in Inches.						
	⅜	7/16	½	⅝	¾	⅞	1
Inches.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
3	9·65	11·0	12·3	14·6	16·6	18·3	19·6
3½	11·5	13·2	14·7	17·6	20·3	22·6	24·5
4	13·3	15·3	17·2	20·7	24·0	26·9	29·5
4½	15·2	17·5	19·6	23·8	27·7	31·1	34·4
5	17·0	19·6	22·1	26·9	31·5	35·4	39·3
5½	18·9	21·8	24·5	29·9	35·2	39·7	44·2
6	20·7	23·9	27·0	33·0	38·9	44·0	49·1
6½	22·5	26·0	29·5	36·1	42·6	48·3	54·0

TABLE 156.—CAST-IRON CYLINDERS (*continued*).

External Diameter.	Thickness in Inches.						
	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1
Inches.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
7	24·4	28·2	31·9	39·1	46·4	52·6	58·9
7½	26·2	30·3	34·4	42·2	50·1	56·9	63·8
8	28·1	32·5	36·8	45·3	53·8	61·2	68·7
8½	29·9	34·6	39·3	48·3	57·5	65·5	73·6
9	31·8	36·8	41·7	51·4	61·3	69·8	78·5
9½	33·6	38·9	44·2	54·5	65·0	74·1	83·5
10	35·4	41·1	46·6	57·5	68·7	78·4	88·4
11	39·1	45·4	51·5	63·7	76·0	87·0	98·2
12	42·8	49·7	56·5	69·8	83·4	95·6	108·0
13	46·5	54·0	61·4	75·9	90·7	104·2	117·8
14	50·2	58·3	66·3	82·1	98·0	112·8	127·6
15	53·8	62·6	71·2	88·2	105·4	121·3	137·4
16	57·5	66·9	76·1	94·3	112·7	129·9	147·3
17	61·2	71·1	81·0	100·5	120·0	138·5	157·1
18	64·9	75·4	85·9	106·6	127·4	147·1	166·9
19	68·6	79·7	90·8	112·8	134·7	155·7	176·7
20	72·3	84·0	95·7	118·9	142·0	164·3	186·5
21	75·9	88·3	100·6	125·0	149·4	172·9	196·4
22	79·6	92·6	105·5	131·2	156·7	181·5	206·2
23	83·3	96·9	110·5	137·3	164·0	190·1	215·0
24	87·0	101·2	115·4	143·4	171·4	198·7	225·8
25	90·7	105·5	120·3	149·6	178·7	207·2	235·6
26	94·3	109·8	125·2	155·7	186·1	215·8	245·4
27	98·0	114·1	130·1	161·8	193·4	224·4	255·3
28	101·7	118·4	135·0	168·0	200·7	233·0	265·1
29	105·4	122·7	139·9	174·1	208·1	241·6	274·9
30	109·1	127·0	144·8	180·2	215·4	250·2	284·7
31	112·8	131·3	149·7	186·4	222·7	258·8	294·5
32	116·4	135·6	154·6	192·5	230·1	267·4	304·3
33	120·1	139·9	159·5	198·7	237·5	276·0	314·2
34	123·8	144·2	164·5	204·8	244·8	284·6	324·0
35	127·5	148·5	169·4	210·9	252·2	293·1	333·8
36	131·2	152·7	174·3	217·1	259·5	301·7	343·6
38	138·5	161·3	184·1	229·3	274·3	318·9	363·2
40	145·9	169·9	193·9	241·6	289·0	336·1	382·9
42	153·3	178·5	203·7	253·9	303·7	353·3	402·5
45	164·3	191·2	218·5	272·3	325·8	379·1	432·0
48	175·4	203·8	233·2	290·7	347·9	404·8	461·4
51	186·4	216·5	247·9	309·1	370·0	430·6	490·9
54	197·5	229·2	262·6	327·5	392·1	456·4	520·3
57	208·5	241·8	277·4	345·9	414·2	482·1	549·8
60	219·6	254·5	292·1	364·3	436·3	507·9	579·3

TABLE 156.—CAST-IRON CYLINDERS (*continued*).

External Diameter.	Thickness in Inches.						
	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1
Inches.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.
63	2·06	2·39	2·74	3·42	4·09	4·77	5·43
66	2·16	2·50	2·87	3·58	4·29	5·00	5·70
69	2·26	2·62	3·00	3·75	4·49	5·23	5·96
72	2·36	2·74	3·14	3·91	4·69	5·46	6·22
75	2·45	2·85	3·27	4·08	4·88	5·69	6·49
78	2·55	2·97	3·40	4·24	5·08	5·92	6·75
81	2·65	3·09	3·53	4·41	5·28	6·15	7·01
84	2·75	3·20	3·66	4·57	5·47	6·38	7·28
90	2·95	3·43	3·92	4·90	5·87	6·84	7·80
96	3·15	3·67	4·19	5·23	6·26	7·30	8·33

External Diameter.	Thickness in Inches.						
	$1\frac{1}{8}$	$1\frac{1}{4}$	$1\frac{3}{8}$	$1\frac{1}{2}$	$1\frac{3}{4}$	2	$2\frac{1}{4}$
Inches.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.
6	·481	·520	·557	·592	·652	·701	·740
$6\frac{1}{2}$	·530	·575	·618	·657	·729	·789	·838
7	·579	·630	·678	·723	·805	·876	·938
$7\frac{1}{2}$	·629	·685	·738	·789	·882	·964	1·04
8	·678	·740	·799	·855	·959	1·05	1·14
$8\frac{1}{2}$	·727	·794	·859	·921	1·04	1·14	1·23
9	·777	·849	·919	·986	1·11	1·23	1·33
$9\frac{1}{2}$	·826	·904	·980	1·05	1·19	1·31	1·43
10	·875	·959	1·04	1·12	1·27	1·40	1·53
11	·974	1·07	1·16	1·25	1·42	1·58	1·73
12	1·07	1·18	1·28	1·38	1·57	1·75	1·92
13	1·17	1·29	1·40	1·51	1·73	1·93	2·12
14	1·27	1·40	1·52	1·64	1·88	2·10	2·32
15	1·37	1·51	1·65	1·78	2·03	2·28	2·52
16	1·47	1·62	1·77	1·91	2·19	2·45	2·71
17	1·57	1·73	1·89	2·04	2·34	2·63	2·91
18	1·66	1·84	2·01	2·17	2·49	2·81	3·11
20	1·86	2·06	2·25	2·43	2·80	3·16	3·50
22	2·06	2·27	2·49	2·70	3·11	3·51	3·90
24	2·26	2·49	2·73	2·96	3·41	3·86	4·29
27	2·55	2·82	3·09	3·35	3·87	4·38	4·88
30	2·85	3·15	3·46	3·75	4·33	4·91	5 47
33	3·14	3·48	3·82	4·14	4·79	5·44	6·06
36	3·44	3·81	4·18	4·54	5·25	5·96	6·66
39	3·74	4·14	4·54	4·93	5·72	6·49	7·25

TABLE 156.—CAST-IRON CYLINDERS (*continued*).

External Diameter.	Thickness in Inches.						
	1⅛	1¼	1⅜	1½	1¾	2	2¼
Inches.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.
42	4·03	4·47	4·90	5·33	6·18	7·01	7·84
45	4·33	4·79	5·26	5·72	6·64	7·54	8·43
48	4·62	5·12	5·62	6·12	7·10	8·07	9·02
51	4·92	5·45	5·98	6·51	7·56	8·59	9·61
54	5·22	5·78	6·35	6·91	8·02	9·12	10·2
57	5·51	6·11	6·71	7·30	8·48	9·64	10·8
60	5·81	6·44	7·07	7·70	8·94	10·2	11·4
Ft. In.							
5 3	6·10	6·77	7·43	8·09	9·40	10·7	12·0
5 6	6·40	7·09	7·79	8·48	9·86	11·2	12·6
5 9	6·70	7·42	8·15	8·88	10·3	11·8	13·2
6 0	7·00	7·75	8·51	9·27	10·8	12·3	13·8
6 3	7·29	8·08	8·88	9·67	11·2	12·8	14·4
6 6	7·58	8·41	9·24	10·1	11·7	13·3	14·9
6 9	7·88	8·74	9·60	10·5	12·2	13·9	15·5
7 0	8·17	9·07	9·96	10·9	12·6	14·4	16·1
7 6	8·77	9·72	10·7	11·6	13·5	15·4	17·3
8 0	9·36	10·4	11·4	12·4	14·5	16·5	18·5
8 6	9·95	11·0	12·1	13·2	15·4	17·5	19·7
9 0	10·5	11·7	12·9	14·0	16·3	18·6	20·8
9 6	11·1	12·3	13·6	14·8	17·2	19·6	22·0
10 0	11·7	13·0	14·3	15·6	18·1	20·7	23·2
10 6	12·3	13·7	15·0	16·4	19·1	21·7	24·4
11 0	12·9	14·3	15·7	17 2	20·0	22·8	25·6
11 6	13·5	15·0	16·5	17·9	20·9	23·8	26·7
12 0	14·1	15·6	17·2	18·7	21·8	24·9	27·9
13 0	15·3	16·9	18·6	20·3	23·7	27·0	30·3
14 0	16·5	18·3	20·1	21·9	25·5	29·1	32·7
15 0	17·7	19·6	21·5	23·5	27·3	31·2	35·0
16 0	18·8	20·9	23·0	25·0	29·2	33·3	37·4
17 0	20·0	22·2	24·4	26·6	31·0	35·4	39·8
18 0	21·2	23·5	25·9	28·2	32·9	37·5	42·2
19 0	22·4	24·8	27·3	29·8	34·7	39·6	44·5
20 0	23·6	26·1	28·8	31·4	36·5	41·7	46·9

TABLE 154.—CAST IRON CYLINDERS (*continued*).

Inside Diam.	Thickness in Inches.										
	⅝	¾	⅞	1	1⅛	1¼	1⅜	1½	1¾	2	2¼
Inch.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.
48	2·66	3·21	3·75	4·30	4·85	5·40	5·96	6·52	7·63	8·77	9·91
51	2·82	3·40	3·98	4·56	5·14	5·73	6·32	6·91	8·09	9·29	10·5
54	2·99	3·60	4·21	4·82	5·44	6·06	6·69	7·31	8·55	9·82	11·1
57	3·15	3·80	4·44	5·09	5·73	6·38	7·05	7·70	9·01	10·4	11·7
60	3·32	4·00	4·67	5·35	6·03	6·71	7·41	8·10	9·47	10·9	12·3
63	3·48	4·19	4·90	5·61	6·33	7·04	7·78	8·49	9·93	11·4	12·9
66	3·64	4·39	5·13	5·88	6·62	7·37	8·14	8·89	10·4	11·9	13·5
69	3·81	4·59	5·36	6·14	6·92	7·70	8·51	9·28	10·9	12·5	14·1
72	3·97	4·78	5·59	6·40	7·21	8·03	8·87	9·67	11·3	13·0	14·7
75	4·14	4·98	5·82	6·66	7·51	8·36	9·24	10·1	11·8	13·5	15·2
78	4·30	5·18	6·05	6·93	7·81	8·69	9·60	10·5	12·2	14·0	15·8
81	4·46	5·38	6·28	7·19	8·10	9·02	9·97	10·9	12·7	14·6	16·4
84	4·63	5·57	6·51	7·45	8·40	9·35	10·3	11·3	13·2	15·1	17·0
87	4·79	5·77	6·74	7·72	8·69	9·67	10·7	11·6	13·6	15·6	17·6
90	4·96	5·97	6·97	7·98	8·99	10·0	11·1	12·0	14·1	16·1	18·2
93	5·12	6·17	7·20	8·24	9·29	10·3	11·4	12·4	14·5	16·7	18·8
96	5·28	6·36	7·43	8·51	9·58	10·7	11·8	12·8	15·0	17·2	19·4
99	5·45	6·56	7·66	8·77	9·88	11·0	12·2	13·2	15·5	17·7	20·0
102	5·61	6·76	7·89	9·03	10·2	11·3	12·5	13·6	15·9	18·2	20·6
105	5·78	6·95	8·12	9·29	10·5	11·7	12·9	14·0	16·4	18·8	21·2
108	5·94	7·15	8·36	9·56	10·8	12·0	13·3	14·4	16·8	19·3	21·8
111	6·10	7·35	8·59	9·82	11·1	12·3	13·6	14·8	17·3	19·8	22·3
114	6·27	7·55	8·82	10·1	11·4	12·6	14·0	15·2	17·8	20·3	22·9
117	6·43	7·74	9·05	10·4	11·7	13·0	14·3	15·6	18·2	20·9	23·5
120	6·59	7·94	9·28	10·6	12·0	13·3	14·7	16·0	18·7	21·4	24·1

TABLE 156.—CAST-IRON CYLINDERS: WEIGHT BY EXTERNAL DIAMETER.

Length, 1 Foot.

External Diameter.	Thickness in Inches.						
	⅜	7/16	½	⅝	¾	⅞	1
Inches.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
3	9·65	11·0	12·3	14·6	16·6	18·3	19·6
3½	11·5	13·2	14·7	17·6	20·3	22·6	24·5
4	13·3	15·3	17·2	20·7	24·0	26·9	29·5
4½	15·2	17·5	19·6	23·8	27·7	31·1	34·4
5	17·0	19·6	22·1	26·9	31·5	35·4	39·3
5½	18·9	21·8	24·5	29·9	35·2	39·7	44·2
6	20·7	23·9	27·0	33·0	38·9	44·0	49·1
6½	22·5	26·0	29·5	36·1	42·6	48·3	54·0

TABLE 156.—CAST-IRON CYLINDERS (*continued*).

External Diameter.	Thickness in Inches.						
	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1
Inches.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
7	24·4	28·2	31·9	39·1	46·4	52·6	58·9
7½	26·2	30·3	34·4	42·2	50·1	56·9	63·8
8	28·1	32·5	36·8	45·3	53·8	61·2	68·7
8½	29·9	34·6	39·3	48·3	57·5	65·5	73·6
9	31·8	36·8	41·7	51·4	61·3	69·8	78·5
9½	33·6	38·9	44·2	54·5	65·0	74·1	83·5
10	35·4	41·1	46·6	57·5	68·7	78·4	88·4
11	39·1	45·4	51·5	63·7	76·0	87·0	98·2
12	42·8	49·7	56·5	69·8	83·4	95·6	108·0
13	46·5	54·0	61·4	75·9	90·7	104·2	117·8
14	50·2	58·3	66·3	82·1	98·0	112·8	127·6
15	53·8	62·6	71·2	88·2	105·4	121·3	137·4
16	57·5	66·9	76·1	94·3	112·7	129·9	147·3
17	61·2	71·1	81·0	100·5	120·0	138·5	157·1
18	64·9	75·4	85·9	106·6	127·4	147·1	166·9
19	68·6	79·7	90·8	112·8	134·7	155·7	176·7
20	72·3	84·0	95·7	118·9	142·0	164·3	186·5
21	75·9	88·3	100·6	125·0	149·4	172·9	196·4
22	79·6	92·6	105·5	131·2	156·7	181·5	206·2
23	83·3	96·9	110·5	137·3	164·0	190·1	215·0
24	87·0	101·2	115·4	143·4	171·4	198·7	225·8
25	90·7	105·5	120·3	149·6	178·7	207·2	235·6
26	94·3	109·8	125·2	155·7	186·1	215·8	245·4
27	98·0	114·1	130·1	161·8	193·4	224·4	255·3
28	101·7	118·4	135·0	168·0	200·7	233·0	265·1
29	105·4	122·7	139·9	174·1	208·1	241·6	274·9
30	109·1	127·0	144·8	180·2	215·4	250·2	284·7
31	112·8	131·3	149·7	186·4	222·7	258·8	294·5
32	116·4	135·6	154·6	192·5	230·1	267·4	304·3
33	120·1	139·9	159·5	198·7	237·5	276·0	314·2
34	123·8	144·2	164·5	204·8	244·8	284·6	324·0
35	127·5	148·5	169·4	210·9	252·2	293·1	333·8
36	131·2	152·7	174·3	217·1	259·5	301·7	343·6
38	138·5	161·3	184·1	229·3	274·3	318·9	363·2
40	145·9	169·9	193·9	241·6	289·0	336·1	382·9
42	153·3	178·5	203·7	253·9	303·7	353·3	402·5
45	164·3	191·2	218·5	272·3	325·8	379·1	432·0
48	175·4	203·8	233·2	290·7	347·9	404·8	461·4
51	186·4	216·5	247·9	309·1	370·0	430·6	490·9
54	197·5	229·2	262·6	327·5	392·1	456·4	520·3
57	208·5	241·8	277·4	345·9	414·2	482·1	549·8
60	219·6	254·5	292·1	364·3	436·3	507·9	579·3

TABLE 156.—CAST-IRON CYLINDERS (*continued*).

External Diameter.	Thickness in Inches.						
	⅜	7/16	½	⅝	¾	⅞	1
Inches.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.
63	2·06	2·39	2·74	3·42	4·09	4·77	5·43
66	2·16	2·50	2·87	3·58	4·29	5·00	5·70
69	2·26	2·62	3·00	3·75	4·49	5·23	5·96
72	2·36	2·74	3·14	3·91	4·69	5·46	6·22
75	2·45	2·85	3·27	4·08	4·88	5·69	6·49
78	2·55	2·97	3·40	4·24	5·08	5·92	6·75
81	2·65	3·09	3·53	4·41	5·28	6·15	7·01
84	2·75	3·20	3·66	4·57	5·47	6·38	7·28
90	2·95	3·43	3·92	4·90	5·87	6·84	7·80
96	3·15	3·67	4·19	5·23	6·26	7·30	8·33

External Diameter.	Thickness in Inches.						
	1⅛	1¼	1⅜	1½	1¾	2	2¼
Inches.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.
6	·481	·520	·557	·592	·652	·701	·740
6½	·530	·575	·618	·657	·729	·789	·838
7	·579	·630	·678	·723	·805	·876	·938
7½	·629	·685	·738	·789	·882	·964	1·04
8	·678	·740	·799	·855	·959	1·05	1·14
8½	·727	·794	·859	·921	1·04	1·14	1·23
9	·777	·849	·919	·986	1·11	1·23	1·33
9½	·826	·904	·980	1·05	1·19	1·31	1·43
10	·875	·959	1·04	1·12	1·27	1·40	1·53
11	·974	1·07	1·16	1·25	1·42	1·58	1·73
12	1·07	1·18	1·28	1·38	1·57	1·75	1·92
13	1·17	1·29	1·40	1·51	1·73	1·93	2·12
14	1·27	1·40	1·52	1·64	1·88	2·10	2·32
15	1·37	1·51	1·65	1·78	2·03	2·28	2·52
16	1·47	1·62	1·77	1·91	2·19	2·45	2·71
17	1·57	1·73	1·89	2·04	2·34	2·63	2·91
18	1·66	1·84	2·01	2·17	2·49	2·81	3·11
20	1·86	2·06	2·25	2·43	2·80	3·16	3·50
22	2·06	2·27	2·49	2·70	3·11	3·51	3·90
24	2·26	2·49	2·73	2·96	3·41	3·86	4·29
27	2·55	2·82	3·09	3·35	3·87	4·38	4·88
30	2·85	3·15	3·46	3·75	4·33	4·91	5·47
33	3·14	3·48	3·82	4·14	4·79	5·44	6·06
36	3·44	3·81	4·18	4·54	5·25	5·96	6·66
39	3·74	4·14	4·54	4·93	5·72	6·49	7·25

TABLE 156.—CAST-IRON CYLINDERS (*continued*).

External Diameter.	Thickness in Inches.						
	1⅛	1¼	1⅜	1½	1¾	2	2¼
Inches.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.
42	4·03	4·47	4·90	5·33	6·18	7·01	7·84
45	4·33	4·79	5·26	5·72	6·64	7·54	8·43
48	4·62	5·12	5·62	6·12	7·10	8·07	9·02
51	4·92	5·45	5·98	6·51	7·56	8·59	9·61
54	5·22	5·78	6·35	6·91	8·02	9·12	10·2
57	5·51	6·11	6·71	7·30	8·48	9·64	10·8
60	5·81	6·44	7·07	7·70	8·94	10·2	11·4
Ft. In.							
5 3	6·10	6·77	7·43	8·09	9·40	10·7	12·0
5 6	6·40	7·09	7·79	8·48	9·86	11·2	12·6
5 9	6·70	7·42	8·15	8·88	10·3	11·8	13·2
6 0	7·00	7·75	8·51	9·27	10·8	12·3	13·8
6 3	7·29	8·08	8·88	9·67	11·2	12·8	14·4
6 6	7·58	8·41	9·24	10·1	11·7	13·3	14·9
6 9	7·88	8·74	9·60	10·5	12·2	13·9	15·5
7 0	8·17	9·07	9·96	10·9	12·6	14·4	16·1
7 6	8·77	9·72	10·7	11·6	13·5	15·4	17·3
8 0	9·36	10·4	11·4	12·4	14·5	16·5	18·5
8 6	9·95	11·0	12·1	13·2	15·4	17·5	19·7
9 0	10·5	11·7	12·9	14·0	16·3	18·6	20·8
9 6	11·1	12·3	13·6	14·8	17·2	19·6	22·0
10 0	11·7	13·0	14·3	15·6	18·1	20·7	23·2
10 6	12·3	13·7	15·0	16·4	19·1	21·7	24·4
11 0	12·9	14·3	15·7	17 2	20·0	22·8	25·6
11 6	13·5	15·0	16·5	17·9	20·9	23·8	26·7
12 0	14·1	15·6	17·2	18·7	21·8	24·9	27·9
13 0	15·3	16·9	18·6	20·3	23·7	27·0	30·3
14 0	16·5	18·3	20·1	21·9	25·5	29·1	32·7
15 0	17·7	19·6	21·5	23·5	27·3	31·2	35·0
16 0	18·8	20·9	23·0	25·0	29·2	33·3	37·4
17 0	20·0	22·2	24·4	26·6	31·0	35·4	39·8
18 0	21·2	23·5	25·9	28·2	32·9	37·5	42·2
19 0	22·4	24·8	27·3	29·8	34·7	39·6	44·5
20 0	23·6	26·1	28·8	31·4	36·5	41·7	46·9

TABLE 157.—CAST-IRON BALLS AND THEIR CIRCUMSCRIBING CYLINDERS: WEIGHTS.

Diameter.	Weight of Ball.	Weight of Circumscribing Cylinder.	Diameter.	Weight of Ball.	Weight of Circumscribing Cylinder.
Inches.	Pounds.	Pounds.	Inches.	Cwts.	Cwts.
2	1·09	1·64	10	1·22	1·83
2½	2·13	3·19	11	1·62	2·43
3	3·68	5·52	12	2·10	3·15
3½	5·85	8·77	14	3·34	5·01
4	8·73	13·1	16	4·99	7·48
4½	12·4	18·6	18	7·10	10·65
5	17·0	25·5	20	9·74	14·61
5½	22·7	34·0	22	12·97	19·45
6	29·5	44·2	24	16·83	25·25
6½	37·5	56·2	26	21·40	32·10
7	46·8	70·2	28	26·72	40·08
7½	57·5	86·2	30	32·87	49·31
8	69·8	104·7			
9	99·4	149·1			

Cylinder, one-half heavier than ball.

TABLE 158.—COPPER AND BRASS: WEIGHT OF ONE LINEAL FOOT OF ROUND BOLTS OR RODS.

(Elliott's Metal Company.)

On the basis of 558lb. per cubic foot of Copper; and 534lb. for Brass.

Diameter.	Copper.	Brass.	Diameter.	Copper.	Brass.
Inches.	Pounds.	Pounds.	Inches.	Pounds.	Pounds.
½	·76	·72	2¼	15·40	14·74
9/16	·96	·92	2⅜	17·16	16·42
⅝	1·19	1·13	2½	19·01	18·19
11/16	1·43	1·37	2⅝	29·96	20·06
¾	1·71	1·63	2¾	23·01	22·01
13/16	2·01	1·92	2⅞	25·15	24·06
⅞	2·33	2·23	3	27·38	26·20
15/16	2·67	2·56	3¼	32·14	30·75
1	3·04	2·91	3½	37·27	35·67
1 1/16	3·43	3·28	3¾	42·78	40·93
1⅛	3·85	3·68	4	48·67	46·57
1 3/16	4·29	4·10	4¼	54·94	52·58
1¼	4·75	4·55	4½	61·61	58·95
1⅜	5·75	5·50	4¾	68·66	65·70
1½	6·84	6·55	5	76·06	72·79
1⅝	8·03	7·68	5¼	83·86	80·24
1¾	9·32	8·91	5½	92·03	88·06
1⅞	10·69	10·23	6	109·55	104·82
2	12·17	11·64	6½	128·57	123·03
2⅛	13·73	13·14	7	149·10	142·68

TABLE 159.—COPPER AND BRASS: WEIGHT OF ONE SQUARE FOOT.

(Elliott's Metal Company.)

On the basis of 558 lb. per cubic foot of Copper and 534 lb. for Brass.

Thickness.	Weight per Square Foot.		Thickness.	Weight per Square Foot.	
	Copper.	Brass.		Copper.	Brass.
I. W. G.	Pounds.	Pounds.	I. W. G.	Pounds.	Pounds.
1	13·950	13·350	22	1·302	1·246
2	12·834	12·282	23	1·116	1·068
3	11·718	11·214	24	1·023	·979
4	10·788	10·324	25	·930	·890
5	9·858	9·434	26	·837	·801
6	8·928	8·544	27	·762	·729
7	8·184	7·832	28	·688	·658
8	7·440	7·120	29	·632	·605
9	6·696	6·408	30	·576	·551
10	5·952	5·696	31	·539	·516
11	5·394	5·162	32	·502	·480
12	4·836	4·628	33	·465	·445
13	4·278	4·094	34	·427	·409
14	3·720	3·560	35	·390	·373
15	3·348	3·204	36	·353	·338
16	2·976	2·848	37	·316	·302
17	2·604	2·492	38	·279	·267
18	2·232	2·136	39	·241	·231
19	1·860	1·780	40	·223	·213
20	1·624	1·602	41	·204	·195
21	1·488	1·424	42	·186	·178

TABLE 160.—COPPER: APPROXIMATE WEIGHT OF ONE SQUARE FOOT.

(Elliott's Metal Company).

Thickness. I. W. G.	Approximate Weight per Square Foot.		Thickness, I. W. G.	Approximate Weight per Square Foot.		Thickness, I. W. G.	Approximate Weight per Square Foot.	
No.	Lbs.	Oz.	No.	Lbs.	Oz.	No.	Lbs.	Oz.
1	14	0	11	5	6	21	1	7½
2	12	14	12	4	13	22	1	5
3	11	12	13	4	4	23	1	2½
4	10	12	14	3	12	24	1	0
5	9	14	15	3	6	25	0	14¾
6	9	0	16	3	0	26	0	13½
7	8	2	17	2	10	27	0	12¼
8	7	6	18	2	4	28	0	11
9	6	11	19	1	14	29	0	10
10	6	0	20	1	10	30	0	9¼

TABLE 157.—CA

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Diameter.	Weight of Ball.	
Inches.	Pounds.	
2	1·09	
2½	2·13	
3	3·68	
3½	5·85	
4	8·73	
4½	12·4	
5	17·0	
5½	22·7	
6	29·5	
6½	37·5	5
7	46·8	7
7½	57·5	8
8	69·8	104
9	99·4	149·

TABLE 158.—COPPER AN
FOOT OF ROU
(Elliott's
On the basis of 558lb. per
fo

Diameter.	Copper.	Brass.				
Inches.	Pounds.	Pounds.				
½	·76	·72				
9/16	·96	·92				
⅝	1·19	1·13				
11/16	1·43	1·37				
¾	1·71	1·63				
13/16	2·01	1·92				
⅞	2·33	2·23				
15/16	2·67	2·56				
1	3·04	2·91				
1 1/16	3·43	3·28	3			
1⅛	3·85	3·68	4			
1 3/16	4·29	4·10	4¼	91		
1¼	4·75	4·55	4½	3·28	3	
1⅜	5·75	5·50	4¾	3·68	4	4
1½	6·84	6·55	5	4·10	4¼	4
1⅝	8·03	7·68	5¼	4·55	4½	4
1¾	9·32	8·91	5½	·50	4	4
1⅞	10·69	10·23	6	·20	4	4
2	12·17	11·64	6½	·22	4	4
2⅛	13·73	13·14	7	10	4	4

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TABLE 161.—WEIGHT OF SEAMLESS COPPER TUBES : IMPERI

Calculated on the basis o

1884.												THICKNESS
I. W. G.		0000	000	00	0	1	2	3	4	5	6	7
Inches.		0·400	0·372	0·348	0·324	0·300	0·276	0·252	0·232	0·212	0·192	0·176
		$\frac{13}{32}$ b	$\frac{3}{8}$ b	$\frac{11}{32}$ f	$\frac{21}{64}$ b	$\frac{19}{64}$ f	$\frac{9}{32}$ b	$\frac{1}{4}$ f	$\frac{15}{64}$ b	$\frac{7}{32}$ b	$\frac{3}{16}$ f	$\frac{11}{64}$ f
Millimetres.		10·160	9·449	8·839	8·229	7·620	7·010	6·401	5·893	5·385	4·877	4·470
Internal Diameter.												WEIGHT OF A LINEAL
Inches.	Millim.											
$\frac{1}{8}$	3·2	2·54	2·24	1·99	1·76	1·54	1·34	1·15	1·00	0·86	0·74	0·64
$\frac{1}{4}$	6·3	3·14	2·80	2·52	2·25	2·00	1·76	1·53	1·35	1·18	1·03	0·91
$\frac{3}{8}$	9·5	3·75	3·36	3·04	2·74	2·45	2·17	1·91	1·70	1·50	1·32	1·17
$\frac{1}{2}$	12·7	4·35	3·92	3·57	3·23	2·90	2·59	2·29	2·05	1·83	1·61	1·44
$\frac{5}{8}$	15·9	4·96	4·49	4·10	3·72	3·36	3·01	2·67	2·40	2·15	1·90	1·70
$\frac{3}{4}$	19·0	5·56	5·05	4·62	4·21	3·81	3·43	3·05	2·76	2·47	2·19	1·97
$\frac{7}{8}$	22·2	6·17	5·61	5·15	4·70	4·26	3·84	3·44	3·11	2·79	2·48	2·24
1	25·4	6·77	6·17	5·67	5·19	4·72	4·26	3·82	3·46	3·11	2·77	2·50
$1\frac{1}{8}$	28·6	7·38	6·74	6·20	5·68	5·17	4·68	4·20	3·81	3·43	3·06	2·77
$1\frac{1}{4}$	31·7	7·98	7·30	6·73	6·17	5·62	5·09	4·58	4·16	3·75	3·35	3·04
$1\frac{3}{8}$	34·9	8·59	7·86	7·25	6·66	6·08	5·51	4·96	4·51	4·07	3·64	3·30
$1\frac{1}{2}$	38·1	9·19	8·42	7·78	7·15	6·53	5·93	5·34	4·86	4·39	3·93	3·57
$1\frac{5}{8}$	41·3	9·80	8·99	8·31	7·64	6·99	6·35	5·72	5·21	4·71	4·22	3·83
$1\frac{3}{4}$	44·4	10·40	9·55	8·83	8·13	7·44	6·76	6·10	5·56	5·03	4·51	4·10
$1\frac{7}{8}$	47·6	11·01	10·11	9·36	8·62	7·89	7·18	6·48	5·91	5·35	4·80	4·37
2	50·8	11·61	10·67	9·88	9·11	8·35	7·60	6·86	6·26	5·67	5·09	4·63
$2\frac{1}{8}$	54·0	12·22	11·24	10·41	9·60	8·80	8·02	7·25	6·61	5·99	5·38	4·90
$2\frac{1}{4}$	57·1	12·82	11·80	10·94	10·09	9·25	8·43	7·63	6·97	6·31	5·67	5·16
$2\frac{3}{8}$	60·3	13·43	12·36	11·46	10·58	9·71	8·85	8·01	7·32	6·63	5·96	5·43
$2\frac{1}{2}$	63·5	14·03	12·92	11·99	11·07	10·16	9·27	8·39	7·67	6·95	6·25	5·70
$2\frac{5}{8}$	66·7	14·64	13·49	12·52	11·56	10·62	9·69	8·77	8·02	7·28	6·54	5·96
$2\frac{3}{4}$	69·8	15·24	14·05	13·04	12·05	11·07	10·10	9·15	8·37	7·60	6·83	6·23
$2\frac{7}{8}$	73·0	15·85	14·61	13·57	12·54	11·52	10·52	9·53	8·72	7·92	7·12	6·50
3	76·2	16·45	15·17	14·09	13·03	11·98	10·94	9·91	9·07	8·24	7·41	6·76
$3\frac{1}{4}$	82·5	17·66	16·30	15·15	14·01	12·88	11·77	10·68	9·77	8·88	7·99	7·29
$3\frac{1}{2}$	88·9	18·87	17·42	16·20	14·99	13·79	12·61	11·44	10·47	9·52	8·58	7·83
$3\frac{3}{4}$	95·2	20·08	18·55	17·25	15·97	14·70	13·44	12·20	11·18	10·16	9·16	8·36
4	101·6	21·20	19·67	18·30	16·95	15·62	14·28	12·96	11·88	10·80	9·74	8·89
$4\frac{1}{4}$	107·9	22·50	20·80	19·36	17·93	16·51	15·11	13·72	12·58	11·44	10·32	9·42
$4\frac{1}{2}$	114·3	23·71	21·93	20·41	18·91	17·42	15·95	14·49	13·28	12·08	10·90	9·96
$4\frac{3}{4}$	120·6	24·92	23·05	21·46	19·89	18·33	16·78	15·25	13·98	12·73	11·48	10·49
5	127·0	26·13	24·18	22·51	20·87	19·23	17·62	16·01	14·68	13·37	12·06	11·02
$5\frac{1}{4}$	133·3	27·34	25·30	23·57	21·85	20·14	18·45	16·77	15·39	14·01	12·64	11·55
$5\frac{1}{2}$	139·7	28·55	26·43	24·62	22·83	21·05	19·29	17·54	16·09	14·65	13·22	12·08
$5\frac{3}{4}$	146·0	29·76	27·55	25·67	23·81	21·96	20·12	18·30	16·79	15·29	13·80	12·62
6	152·4	30·97	28·68	26·72	24·79	22·86	20·95	19·06	17·49	15·93	14·38	13·15
$6\frac{1}{4}$	158·7	32·18	29·80	27·78	25·77	23·77	21·79	19·82	18·19	16·57	14·96	13·68
$6\frac{1}{2}$	165·1	33·39	30·93	28·83	26·75	24·68	22·62	20·58	18·89	17·21	15·54	14·21

Note to Table.—If the External Diameter is given, subtract
Weight per Lineal Foot of a Copper Tube 2 ins. external

Wire Gauge, 1884 (The Broughton Copper Company).
the specific gravity, 8·8917.

of Copper.

8	9	10	11	12	13	14	15	16	17	18	19	20
0·160	0·144	0·128	0·116	0·104	0·092	0·080	0·072	0·064	0·056	0·048	0·040	0·036
$\frac{5}{32}$ *f*	$\frac{9}{64}$ *f*	$\frac{1}{8}$ *f*	$\frac{7}{64}$ *f*	$\frac{7}{64}$ *b*	$\frac{3}{32}$	$\frac{5}{64}$ *f*	$\frac{5}{64}$ *b*	$\frac{1}{16}$ *f*	$\frac{1}{16}$ *b*	$\frac{3}{64}$ *f*	$\frac{3}{64}$ *b*	$\frac{1}{32}$ *f*
4·064	3·658	3·251	2·946	2·642	2·337	2·032	1·829	1·626	1·422	1·219	1·016	0·914

Foot in Pounds.

0·55	0·47	0·39	0·34	0·29	0·24	0·20	0·17	0·15	0·12	0·10	0·08	0·07
0·79	0·69	0·58	0·51	0·44	0·38	0·32	0·28	0·24	0·21	0·17	0·14	0·12
1·04	0·90	0·78	0·69	0·60	0·52	0·44	0·39	0·34	0·29	0·25	0·20	0·18
1·28	1·12	0·97	0·86	0·76	0·66	0·56	0·50	0·44	0·38	0·32	0·26	0·23
1·52	1·34	1·17	1·04	0·92	0·80	0·68	0·61	0·53	0·46	0·39	0·32	0·29
1·76	1·56	1·36	1·21	1·07	0·94	0·80	0·72	0·63	0·55	0·46	0·38	0·34
2·00	1·77	1·55	1·39	1·23	1·08	0·92	0·82	0·73	0·63	0·54	0·44	0·40
2·24	1·99	1·75	1·57	1·39	1·21	1·04	0·93	0·82	0·71	0·61	0·50	0·45
2·49	2·21	1·94	1·74	1·55	1·35	1·17	1·04	0·92	0·80	0·68	0·56	0·51
2·73	2·43	2·13	1·92	1·70	1·49	1·29	1·15	1·02	0·88	0·75	0·62	0·56
2·97	2·65	2·33	2·09	1·86	1·63	1·41	1·26	1·11	0·97	0·83	0·68	0·61
3·21	2·86	2·52	2·27	2·02	1·77	1·53	1·37	1·21	1·05	0·90	0·74	0·67
3·45	3·08	2·71	2·44	2·17	1·91	1·65	1·48	1·31	1·14	0·97	0·81	0·72
3·70	3·30	2·91	2·62	2·33	2·05	1·77	1·59	1·40	1·22	1·04	0·87	0·78
3·94	3·52	3·10	2·79	2·49	2·19	1·89	1·70	1·50	1·31	1·12	0·93	0·83
4·18	3·73	3·29	2·97	2·65	2·33	2·01	1·80	1·60	1·39	1·19	0·99	0·89
4·42	3·95	3·49	3·14	2·80	2·47	2·13	1·91	1·69	1·48	1·26	1·05	0·94
4·66	4·17	3·68	3·32	2·96	2·61	2·25	2·02	1·79	1·56	1·33	1·11	1·00
4·91	4·39	3·88	3·50	3·12	2·75	2·38	2·13	1·89	1·65	1·41	1·17	1·05
5·15	4·61	4·07	3·67	3·28	2·88	2·50	2·24	1·98	1·73	1·48	1·23	1·10
5·39	4·82	4·26	3·85	3·43	3·02	2·62	2·35	2·08	1·82	1·55	1·29	1·16
5·63	5·04	4·46	4·02	3·59	3·16	2·74	2·46	2·18	1·90	1·62	1·35	1·21
5·87	5·26	4·65	4·20	3·75	3·30	2·86	2·57	2·27	1·99	1·70	1·41	1·27
6·12	5·48	4·84	4·37	3·90	3·44	2·98	2·68	2·37	2·07	1·77	1·47	1·32
6·60	5·91	5·23	4·72	4·22	3·72	3·22	2·89	2·57	2·24	1·91	1·59	1·43
7·08	6·35	5·62	5·07	4·53	4·00	3·46	3·11	2·76	2·41	2·06	1·71	1·54
7·57	6·78	6·00	5·42	4·85	4·28	3·71	3·33	2·95	2·58	2·20	1·83	1·65
8·06	7·22	6·30	5·77	5·16	4·55	3·95	3·55	3·15	2·75	2·35	1·95	1·76
8·54	7·65	6·78	6·13	5·48	4·83	4·19	3·76	3·34	2·92	2·50	2·08	1·87
9·02	8·09	7·17	6·48	5·79	5·11	4·43	3·98	3·53	3·09	2·64	2·20	1·97
9·50	8·53	7·55	6·83	6·11	5·39	4·67	4·20	3·73	3·26	2·79	2·32	2·08
9·99	8·96	7·94	7·18	6·42	5·67	4·92	4·42	3·92	3·42	2·93	2·44	2·19
10·47	9·40	8·33	7·53	6·74	5·95	5·16	4·64	4·11	3·59	3·08	2·56	...
10·96	9·83	8·71	7·88	7·05	6·22	5·40	4·85	4·31	3·76	3·22	2·68	...
11·44	10·27	9·10	8·23	7·36	6·50	5·64	5·07	4·50	3·93	3·37	2·80	...
11·92	10·70	9·49	8·58	7·68	6·78	5·88	5·29	4·69	4·10	3·51	2·92	...
12·41	11·14	9·88	8·93	7·99	7·06	6·13	5·51	4·89	4·27	3·66	...	...
12·89	11·57	10·26	9·28	8·31	7·84	6·37	5·72	5·08	4·44	3·80	...	...

number at bottom of column, pages 304, 305. For example—The diameter, 12 I. W. G., is 2·65 – 0·26 = 2·39 lbs. *f*, full; *b*, bare.

TABLE 161.—WEIGHT OF SEAMLESS COPPER TUBES: IMPERIAL

Calculated on the basis of

1884.		THICKNESS										
I. W. G.		0000	000	00	0	1	2	3	4	5	6	7
Inches.		0·400	0·372	0·348	0·324	0·300	0·276	0·252	0·232	0·212	0·192	0·176
		$\frac{13}{32}$ b	$\frac{3}{8}$ b	$\frac{11}{32}$ f	$\frac{21}{64}$ b	$\frac{19}{64}$ f	$\frac{9}{32}$ b	$\frac{1}{4}$ f	$\frac{15}{64}$ b	$\frac{7}{32}$ b	$\frac{3}{16}$ f	$\frac{11}{64}$ f
Millimetres.		10·160	9·449	8·839	8·229	7·620	7·010	6·401	5·893	5·385	4·877	4·470
Internal Diameter.		WEIGHT OF A LINEAL										
Inches.	Millim.											
6¾	171·4	34·60	32·05	29·88	27·73	25·59	23·46	21·35	19·60	17·85	16·12	14·75
7	177·8	35·81	33·18	30·93	28·71	26·49	24·29	22·11	20·30	18·50	16·70	15·28
7¼	184·1	37·02	34·30	31·99	29·69	27·40	25·13	22·87	21·00	19·14	17·29	15·81
7½	190·5	38·23	35·43	33·04	30·67	28·31	25·96	23·63	21·70	19·78	17·87	16·34
7¾	196·8	39·44	36·55	34·09	31·65	29·22	26·80	24·39	22·40	20·42	18·45	16·88
8	203·2	40·65	37·68	35·14	32·63	30·12	27·63	25 16	23·10	21·06	19·08	17·41
8¼	209·5	41·86	38·80	36·20	33·61	31·03	28·47	25·92	23·81	21·70	19·61	17·94
8½	215·9	43·07	39·93	37·25	34·59	31·94	29·30	26·68	24·51	22·34	20·19	18·47
8¾	222·2	44·28	41·05	38·30	35·57	32·84	30·14	27·44	25·21	22·98	20·77	19·00
9	228·6	45·49	42·18	39·35	36·55	33·75	30·97	28·21	25·91	23·63	21·35	19·54
9¼	234·9	46·70	43·30	40·41	37·53	34·66	31·81	28·97	26·61	24·27	21·93	20·07
9½	241·3	47·91	44·43	41·46	38·51	35·57	32·64	29·73	27·31	24·91	22·51	20·60
9¾	247·6	49·12	45·55	42·51	39·49	36·47	33·48	30·49	28·02	25·55	23·09	21·13
10	254·0	50·33	46·68	43·56	40·47	37·38	34·31	31·25	28·72	26·19	23·67	21·67
10¼	260·3	51·54	47·80	44·62	41·45	38·29	35·15	32·02	29·42	26·83	24·25	22·20
10½	266·7	52·75	48·93	45·67	42·43	39·20	35·98	32·78	30·12	27·47	24·83	22·73
10¾	273·0	53·96	50·05	46·72	43·41	40·10	36·81	33·54	30·82	28·11	25·42	23·26
11	279·4	55·16	51·18	47·77	44·39	41·01	37·65	34·30	31·52	28·75	26·00	23·80
11¼	285·7	56·37	52·30	48·83	45·37	41·92	38·48	35·06	32·23	29·40	26·58	24·33
11½	292·1	57·58	53·43	49·88	46·35	42·83	39·32	35·83	32·93	30·04	27·16	24·86
11¾	298·4	58·79	54·55	50·93	47·33	43·73	40·15	36·59	33·63	30·68	27·74	25·39
12	304·8	60·00	55·68	51·98	48·31	44·64	40·99	37·35	34·33	31·32	28·32	25·92
12¼	311·1	61·21	56·80	53·04	49·29	45·55	41·82	38·11	35·03	31·96	28·90	26·46
12½	317·5	62·42	57·93	54·09	50·26	46·45	42·66	38·88	35·73	32·60	29·48	26·99
12¾	323·8	63·63	59·05	55·14	51·24	47·36	43·49	39·64	36·44	33·24	30·06	27·52
13	330·2	64·84	60·18	56·19	52·22	48·27	44·33	40·40	37·14	33·88	30·64	28·05
13¼	336·5	66·05	61·30	57·25	53·20	49·18	45·16	41·16	37·84	34·53	31·22	28·59
13½	342·9	67·26	62·43	58·30	54·18	50·08	46·00	41·92	38·54	35·17	31·80	29·12
13¾	349·2	68·47	63·55	59·35	55·16	50·99	46·83	42·69	39·24	35·81	32·38	29·65
14	355·6	69·68	64·68	60·40	56·14	51·90	47·67	43·45	39·94	36·45	32·96	30·18
		3·87	3·35	2·93	2·54	2·18	1·84	1·54	1·30	1·09	0·89	0·75

Note to Table.—If the External Diameter is given, subtract
Lineal Foot of a Copper Tube 2 ins. external diameter,

WIRE GAUGE, 1884 (The Broughton Copper Co.) (*continued*).

the specific gravity, 8·8917.

OF COPPER.

8	9	10	11	12	13	14	15	16	17	18	19	20
0·160	0·144	0·128	0·116	0·104	0·092	0·080	0·072	0·064	0·056	0·048	0·040	0·036
$\frac{5}{32}$ *f*	$\frac{9}{64}$ *f*	$\frac{1}{8}$ *f*	$\frac{7}{64}$ *f*	$\frac{7}{64}$ *b*	$\frac{3}{32}$	$\frac{5}{64}$ *f*	$\frac{5}{64}$ *b*	$\frac{1}{16}$ *f*	$\frac{1}{16}$ *b*	$\frac{3}{64}$ *f*	$\frac{3}{64}$ *b*	$\frac{1}{32}$ *f*
4·064	3·658	3·251	2·946	2·642	2·337	2·032	1·829	1·626	1·422	1·219	1·016	0·914
FOOT IN POUNDS.												
13·37	12·01	10·65	9·63	8·62	7·61	6·61	5·94	5·28	4·61	3·95	...	...
13·86	12·44	11·04	9·99	8·94	7·89	6·85	6·16	5·47	4·78	4·09	...	...
14·34	12·88	11·42	10·34	9·25	8·17	7·09	6·38	5·66	4·95	...	...	...
14·83	13·32	11·81	10·69	9·57	8·45	7·34	6·60	5·86	5·12	...	...	...
15·31	13·75	12·20	11·04	9·88	8·73	7·58	6·81	6·05	5·29	...	...	...
15·79	14·19	12·59	11·39	10·20	9·01	7·82	7·03	6·24	5·46	...	...	...
16·28	14·62	12·97	11·74	10·51	9·28	8·06	7·25	6·44	...	...	...	...
16·76	15·06	13·36	12·09	10·82	9·56	8·30	7·47	6·63	...	...	...	...
17·25	15·49	13·75	12·44	11·14	9·84	8·55	7·68	6·82	...	...	...	...
17·73	15·93	14·13	12·79	11·45	10·12	8·79	7·90	7·02	...	...	...	...
18·21	16·36	14·52	13·14	11·77	10·40	9·03	8·12	...	...	...	...	...
18·70	16·80	14·91	13·49	12·08	10·68	9·27	8·34	...	...	...	...	...
19·18	17·24	15·30	13·84	12·40	10·95	9·51	8·55	...	...	...	...	...
19·67	17·67	15·68	14·20	12·71	11·23	9·76	8·77	...	...	...	...	...
20·15	18·11	16·07	14·55	13·03	11·51	10·00	...	...	...	...	...	...
20·63	18·54	16·46	14·90	13·34	11·79	10·24	...	...	...	...	...	...
21·12	18·98	16·84	15·25	13·66	12·07	10·48	...	...	...	...	...	...
21·60	19·41	17·23	15·60	13·97	12·34	10·72	...	...	...	...	...	...
22·08	19·85	17·62	15·95	14·28	12·62	...	...	...	...	...	...	...
22·57	20·28	18·01	16·30	14·60	12·90	...	...	...	...	...	...	...
23·05	20·72	18·39	16·65	14·91	13·18	...	...	...	...	...	...	...
23·54	21·16	18·78	17·00	15·23	13·46	...	...	...	...	...	...	...
24·02	21·59	19·17	17·35	15·54	...	...	...	...	...	...	...	...
24·50	22·03	19·55	17·70	15·86	...	...	...	...	...	...	...	...
24·99	22·46	19·94	18·05	16·17	...	...	...	...	...	...	...	...
25·47	22·90	20·33	18·41	16·49	...	...	...	...	...	...	...	...
25·96	23·33	20·72	18·76	...	...	...	...	...	...	...	...	...
26·44	23·77	21·10	19·11	...	...	...	...	...	...	...	...	...
26·92	24·20	21·49	19·46	...	...	...	...	...	...	...	...	...
27·41	24·64	21·88	19·81	...	...	...	...	...	...	...	...	...
0·62	0·50	0·40	0·33	0·26	0·20	0·15	0·12	0·10	0·08	0·06	0·04	0·03

number at bottom of column ; for example—The Weight per
12 I. W. G., is 2·65 − 0·26 = 2·39 lbs. *f*, full ; *b*, bare.

TABLE 162.—WEIGHT OF SEAMLESS COPPER TUBES:

Calculated on the basis of

		THICKNESS										
B. W. G.		0000	000	00	0	1	2	3	4	5	6	7
Inches.		0·454	0·425	0·380	0·340	0·300	0·284	0·259	0·238	0·220	0·203	0·180
		$\frac{29}{64}$	$\frac{27}{64}$ f	$\frac{3}{8}$ f	$\frac{11}{32}$	$\frac{19}{64}$ f	$\frac{9}{32}$ f	$\frac{1}{4}$ f	$\frac{15}{64}$ f	$\frac{7}{32}$ f	$\frac{13}{64}$	$\frac{3}{16}$ b
Millimetres.		11·53	10·79	9·65	8·64	7·62	7·21	6·58	6·04	5·59	5·16	4·57
Internal Diameter.		WEIGHT OF A LINEAL										
Inches.	Millim.											
⅛	3·2	3·18	2·83	2·32	1·91	1·54	1·40	1·20	1·04	0·92	0·80	0·66
¼	6·3	3·87	3·47	2·90	2·43	2·00	1·83	1·59	1·40	1·25	1·11	0·94
⅜	9·5	4·55	4·11	3·47	2·94	2·45	2·26	1·99	1·76	1·58	1·42	1·21
½	12·7	5·24	4·76	4·04	3·45	2·90	2·69	2·38	2·12	1·92	1·78	1·48
⅝	15·9	5·92	5·40	4·62	3·97	3·36	3·12	2·77	2·48	2·25	2·03	1·75
¾	19·0	6·61	6·04	5·19	4·48	3·81	3·55	3·16	2·84	2·58	2·34	2·02
⅞	22·2	7·30	6·68	5·77	5·00	4·26	3·98	3·55	3·20	2·91	2·65	2·30
1	25·4	7·99	7·33	6·34	5·51	4·72	4·41	3·94	3·56	3·25	2·95	2·57
1⅛	28·6	8·67	7·97	6·92	6·03	5·17	4·84	4·34	3·92	3·58	3·26	2·84
1¼	31·7	9·36	8·61	7·49	6·54	5·62	5·27	4·73	4·28	3·91	3·57	3·11
1⅜	34·9	10·04	9·25	8·07	7·05	6·08	5·70	5·12	4·64	4·24	3·87	3·39
1½	38·1	10·73	9·90	8·64	7·57	6·53	6·13	5·51	5·00	4·58	4·18	3·66
1⅝	41·3	11·42	10·54	9·22	8·08	6·99	6·56	5·90	5·36	4·91	4·49	3·93
1¾	44·4	12·10	11·18	9·79	8·60	7·44	6·99	6·29	5·72	5·24	4·80	4·20
1⅞	47·6	12·79	11·82	10·37	9·11	7·89	7·42	6·69	6·08	5·58	5·10	4·47
2	50·8	13·48	12·47	10·94	9·62	8·35	7·85	7·08	6·44	5·91	5·41	4·75
2⅛	54·0	14·16	13·11	11·52	10·14	8·80	8·28	7·47	6·80	6·24	5·72	5·02
2¼	57·1	14·85	13·75	12·09	10·65	9·25	8·71	7·86	7·16	6·57	6·02	5·29
2⅜	60·3	15·54	14·40	12·66	11·17	9·71	9·14	8·25	7·52	6·91	6·33	5·56
2½	63·5	16·22	15·04	13·24	11·68	10·16	9·56	8·64	7·88	7·24	6·64	5·84
2⅝	66·7	16·91	15·68	13·81	12·20	10·62	9·99	9·04	8·24	7·57	6·94	6·11
2¾	69·8	17·60	16·32	14·39	12·71	11·07	10·42	9·43	8·60	7·90	7·25	6·38
2⅞	73·0	18·28	16·97	14·96	13·22	11·52	10·85	9·82	8·96	8·24	7·56	6·65
3	76·2	18·97	17·61	15·54	13·74	11·98	11·28	10·21	9·32	8·57	7·87	6·92
3¼	82·5	20·34	18·89	16·69	14·77	12·88	12·14	10·99	10·04	9·23	8·48	7·47
3½	88·9	21·72	20·18	17·84	15·79	13·79	13·00	11·78	10·76	9·90	9·09	8·01
3¾	95·2	23·09	21·47	18·99	16·82	14·70	13·86	12·56	11·48	10·57	9·71	8·56
4	101·6	24·46	22·75	20·13	17·85	15·61	14·72	13·34	12·20	11·23	10·32	9·10
4¼	107·9	25·84	24·04	21·28	18·88	16·51	15·58	14·13	12·92	11·90	10·94	9·65
4½	114·3	27·21	25·32	22·43	19·91	17·42	16·44	14·91	13·64	12·56	11·55	10·19
4¾	120·6	28·58	26·61	23·58	20·94	18·33	17·29	15·69	14·36	13·23	12·16	10·73
5	127·0	29·95	27·89	24·73	21·96	19·23	18·15	16·48	15·08	13·89	12·78	11·28
5¼	133·3	31·33	29·18	25·88	22·99	20·14	19·01	17·26	15·80	14·56	13·39	11·82
5½	139·7	32·70	30·4[illegible]	27·03	24·02	21·05	19·87	18·04	16·52	15·22	14·01	12·37
5¾	146·0	34·07	31·75	28·18	25·05	21·96	20·73	18·83	17·24	15·89	14·62	12·91
6	152·4	35·45	33·03	29·33	26·08	22·8[illegible]	21·59	19·61	17·96	16·55	15·23	13·46
6¼	158·7	36·82	34·3[illegible]	30·48	27·11	23·77	22·45	20·39	18·68	17·22	15·85	14·00
6½	165·1	38·19	35·60	31·63	28·13	24·68	23·31	21·18	19·40	17·88	16·46	14·55

Note to Table.—If the External Diameter is given, subtract
The Weight per Lineal Foot of a Copper Tube 2 ins. external

BIRMINGHAM WIRE GAUGE (The Broughton Copper Co.).

the specific gravity, 8·8917.

OF COPPER.

8	9	10	11	12	13	14	15	16	17	18	19	20
0·165	0·148	0·134	0·120	0·109	0·095	0·083	0·072	0·065	0·058	0·049	0·042	0·035
$\frac{11}{64}$ *b*	$\frac{9}{64}$ *f*	$\frac{9}{64}$ *b*	$\frac{1}{8}$ *b*	$\frac{7}{64}$	$\frac{3}{32}$ *f*	$\frac{5}{64}$ *f*	$\frac{5}{64}$ *b*	$\frac{1}{16}$ *f*	$\frac{1}{16}$ *b*	$\frac{3}{64}$ *f*	$\frac{3}{64}$ *b*	$\frac{1}{32}$ *f*
4·19	3·76	3·40	3·05	2·77	2·41	2·11	1·83	1·65	1·47	1·24	1·07	0·89

FOOT IN POUNDS.

0·58	0·49	0·42	0·36	0·31	0·25	0·21	0·17	0·15	0·13	0·10	0·08	0·07
0·83	0·71	0·62	0·54	0·47	0·40	0·33	0·2	0·25	0·22	0·18	0·15	0·12
1·08	0·94	0·82	0·72	0·64	0·54	0·46	0·39	0·35	0·30	0·25	0·21	0·17
1·33	1·16	1·03	0·90	0·80	0·68	0·58	0·50	0·44	0·39	0·32	0·27	0·23
1·58	1·38	1·23	1·08	0·97	0·83	0·71	0·61	0·54	0·48	0·40	0·34	0·28
1·83	1·61	1·43	1·26	1·13	0·97	0·84	0·72	0·64	0·57	0·47	0·40	0·33
2·08	1·83	1·64	1·44	1·30	1·11	0·96	0·82	0·74	0·65	0·55	0·47	0·38
2·32	2·05	1·84	1·63	1·46	1·26	1·09	0·93	0·84	0·74	0·62	0·53	0·44
2·57	2·28	2·04	1·81	1·63	1·40	1·21	1·04	0·94	0·83	0·70	0·59	0·49
2·82	2·50	2·24	1·99	1·79	1·55	1·34	1·15	1·03	0·92	0·77	0·66	0·54
3·07	2·73	2·45	2·17	1·96	1·69	1·46	1·26	1·13	1·00	0·84	0·72	0·60
3·32	2·95	2·65	2·35	2·12	1·83	1·59	1·37	1·23	1·09	0·92	0·78	0·65
3·57	3·17	2·85	2·53	2·29	1·98	1·71	1·48	1·33	1·18	0·99	0·85	0·70
3·82	3·40	3·05	2·71	2·45	2·12	1·84	1·59	1·43	1·27	1·07	0·91	0·76
4·07	3·62	3·26	2·90	2·62	2·26	1·97	1·70	1·52	1·36	1·14	0·97	0·81
4·32	3·85	3·46	3·08	2·78	2·41	2·09	1·80	1·62	1·44	1·21	1·04	0·86
4·57	4·07	3·66	3·26	2·95	2·55	2·22	1·91	1·72	1·53	1·29	1·10	0·91
4·82	4·29	3·86	3·44	3·11	2·69	2·34	2·02	1·82	1·62	1·36	1·16	0·97
5·07	4·52	4·07	3·62	3·27	2·84	2·47	2·13	1·92	1·71	1·44	1·23	1·02
5·32	4·74	4·27	3·80	3·44	2·98	2·59	2·24	2·02	1·79	1·51	1·29	1·07
5·57	4·96	4·47	3·98	3·60	3·13	2·72	2·35	2·11	1·88	1·58	1·35	1·13
5·82	5·19	4·67	4·17	3·77	3·27	2·84	2·46	2·21	1·97	1·66	1·42	1·18
6·07	5·41	4·88	4·35	3·93	3·41	2·97	2·57	2·31	2·06	1·73	1·48	1·23
6·32	5·64	5·08	4·53	4·10	3·56	3·10	2·68	2·41	2·15	1·81	1·55	1·28
6·82	6·08	5·49	4·89	4·43	3·84	3·35	2·89	2·61	2·32	1·96	1·67	1·39
7·32	6·53	5·89	5·25	4·76	4·13	3·60	3·11	2·80	2·50	2·10	1·80	1·50
7·81	6·98	6·30	5·62	5·09	4·42	3·85	3·33	3·00	2·67	2·25	1·93	1·60
8·31	7·43	6·70	5·98	5·42	4·71	4·10	3·55	3·20	2·85	2·40	2·05	1·71
8·81	7·87	7·11	6·34	5·75	4·99	4·35	3·76	3·39	3·02	2·55	2·18	1·81
9·31	8·32	7·51	6·71	6·08	5·28	4·60	3·98	3·59	3·20	2·70	2·31	1·92
9·81	8·77	7·92	7·07	6·41	5·57	4·85	4·20	3·79	3·37	2·84	2·43	2·03
10·31	9·22	8·32	7·43	6·74	5·86	5·10	4·42	3·98	3·55	2·99	2·56	2·13
10·81	9·66	8·73	7·80	7·07	6·14	5·35	4·64	4·18	3·72	3·14	2·69	...
11·31	10·11	9·13	8·16	7·40	6·43	5·61	4·85	4·38	3·90	3·29	2·82	...
11·81	10·56	9·54	8·52	7·73	6·72	5·86	5·07	4·57	4·07	3·44	2·94	...
12·31	11·01	9·94	8·88	8·06	7·00	6·11	5·29	4·77	4·25	3·59	3·07	...
12·80	11·45	10·35	9·25	8·38	7·29	6·36	5·51	4·97	4·43	3·73	...	...
13·30	11·90	10·75	9·61	8·71	7·58	6·61	5·72	5·16	4·60	3·88	...	...

number given at bottom of column, pages 308, 309. For example—diameter, 12 B. W. G., is 2·78 0·29 = 2·49 lbs. *f*, full ; *b*, bare.

TABLE 162.—WEIGHT OF SEAMLESS COPPER TUBES: BIRMING-

Calculated on the basis of

		THICKNESS										
B. W. G.		0000	000	00	0	1	2	3	4	5	6	7
Inches.		0·454	0·425	0·380	0·340	0·300	0·284	0·259	0·238	0·220	0·203	0·180
		$\frac{29}{64}$	$\frac{27}{64}$ f	$\frac{3}{8}$ f	$\frac{11}{32}$	$\frac{19}{64}$ f	$\frac{9}{32}$ f	$\frac{1}{4}$ f	$\frac{15}{64}$ f	$\frac{7}{32}$ f	$\frac{13}{64}$	$\frac{3}{16}$ b
Millimetres.		11·53	10·79	9·65	8·64	7·62	7·21	6·58	6·04	5·59	5·16	4·57
Internal Diameter.		WEIGHT OF A LINEAL										
Inches.	Millim.											
6¾	171·4	39·57	36·89	32·78	29·16	25·59	24·17	21·96	20·12	18·55	17·07	15·09
7	177·8	40·94	38·18	33·93	30·19	26·49	25·03	22·74	20·84	19·22	17·69	15·63
7¼	184·1	42·31	39·46	35·08	31·22	27·40	25·88	23·53	21·56	19·88	18·30	16·18
7½	190·5	43·69	40·75	36·22	32·25	28·31	26·74	24·31	22·28	20·55	18·92	16·72
7¾	196·8	45·06	42·03	37·37	33·28	29·22	27·60	25·09	23·00	21·21	19·53	17·27
8	203·2	46·43	43·32	38·52	34·30	30·12	28·46	25·88	23·72	21·88	20·14	17·81
8¼	209·5	47·80	44·60	39·67	35·33	31·03	29·32	26·66	24·44	22·54	20·76	18·36
8½	215·9	49·18	45·89	40·82	36·36	31·94	30·18	27·44	25·16	23·21	21·37	18·90
8¾	222·3	50·55	47·17	41·97	37·39	32·84	31·04	28·23	25·88	23·87	21·99	19·45
9	228·6	51·92	48·46	43·12	38·42	33·75	31·90	29·01	26·60	24·54	22·60	19·99
9¼	235·0	53·30	49·74	44·27	39·45	34·66	32·76	29·79	27·32	25·20	23·21	20·53
9½	241·3	54·67	51·03	45·42	40·47	35·57	33·61	30·58	28·04	25·87	23·83	21·08
9¾	247·7	56·04	52·31	46·57	41·50	36·47	34·47	31·36	28·76	26·53	24·44	21·62
10	254·0	57·42	53·60	47·72	42·53	37·38	35·33	32·14	29·48	27·20	25·06	22·17
10¼	260·4	58·79	54·89	48·87	43·56	38·29	36·19	32·93	30·20	27·87	25·67	22·71
10½	266·7	60·16	56·17	50·02	44·59	39·20	37·05	33·71	30·92	28·53	26·28	23·26
10¾	273·1	61·54	57·46	51·17	45·61	40·10	37·91	34·49	31·64	29·20	26·90	23·80
11	279·4	62·91	58·74	52·31	46·64	41·01	38·77	35·28	32·36	29·86	27·51	24·34
11¼	285·8	64·28	60·03	53·46	47·67	41·92	39·63	36·06	33·08	30·53	28·13	24·89
11½	292·1	65·65	61·31	54·61	48·70	42·83	40·49	36·84	33·80	31·19	28·74	25·43
11¾	298·5	67·03	62·60	55·76	49·73	43·73	41·35	37·63	34·52	31·86	29·35	25·98
12	304·8	68·40	63·88	56·91	50·76	44·64	42·20	38·41	35·24	32·52	29·97	26·52
12¼	311·2	69·77	65·17	58·06	51·78	45·55	43·06	39·19	35·96	33·19	30·58	27·07
12½	317·5	71·15	66·45	59·21	52·81	46·45	43·92	39·98	36·68	33·85	31·20	27·61
12¾	323·9	72·52	67·74	60·36	53·84	47·36	44·78	40·76	37·40	34·52	31·81	28·16
13	330·2	73·89	69·02	61·51	54·87	48·27	45·64	41·54	38·11	35·18	32·42	28·70
13¼	336·6	75·27	70·31	62·66	55·90	49·18	46·50	42·33	38·83	35·85	33·04	29·24
13½	342·9	76·64	71·59	63·81	56·93	50·08	47·36	43·11	39·55	36·52	33·65	29·79
13¾	349·3	78·01	72·88	64·96	57·95	50·99	48·22	43·89	40·27	37·18	34·27	30·33
14	355·6	79·39	74·17	66·11	58·98	51·90	49·08	44·68	40·99	37·85	34·88	30·88
		4·99	4·37	3·49	2·80	2·18	1·95	1·62	1·37	1·17	1·00	0·78

Note to Table.—If the External Diameter is given, subtract
per Lineal Foot of a Copper Tube 2 ins. external diameter,

HAM WIRE GAUGE (The Broughton Copper Co.) (*continued*).

the specific gravity, 8·8917

OF COPPER.

8 0·165 $\frac{11}{64}$ *b* 4·19	9 0·148 $\frac{9}{64}$ *f* 3·76	10 0·134 $\frac{9}{64}$ *b* 3·40	11 0·120 $\frac{1}{8}$ *b* 3·05	12 0·109 $\frac{7}{64}$ 2·77	13 0·095 $\frac{3}{32}$ *f* 2·41	14 0·083 $\frac{5}{64}$ *f* 2·11	15 0·072 $\frac{5}{64}$ *b* 1·83	16 0·065 $\frac{1}{16}$ *f* 1·65	17 0·058 $\frac{1}{16}$ *b* 1·47	18 0·049 $\frac{3}{64}$ *f* 1·24	19 0·042 $\frac{3}{64}$ *b* 1·07	20 0·035 $\frac{1}{32}$ *f* 0·89

FOOT IN POUNDS.

13·80	12·35	11·16	9·97	9·04	7·87	6·86	5·94	5·36	4·78	4·03	...	...
14·30	12·80	11·56	10·34	9·37	8·15	7·11	6·16	5·55	4·95	4·18	...	...
14·80	13·25	11·97	10·70	9·70	8·44	7·36	6·38	5·75	5·13	...	...	...
15·30	13·69	12·37	11·06	10·03	8·73	7·61	6·59	5·95	5·30	...	...	...
15·80	14·14	12·78	11·42	10·36	9·02	7·86	6·81	6·14	5·48	...	...	...
16·30	14·59	13·19	11·79	10·69	9·30	8·12	7·03	6·34	5·65	...	...	...
16·80	15·04	13·59	12·15	11·02	9·59	8·37	7·25	6·54	...	...	...	...
17·30	15·48	14·00	12·51	11·35	9·88	8·62	7·47	6·73	...	...	...	...
17·79	15·93	14·40	12·88	11·68	10·16	8·87	7·68	6·93	...	...	...	...
18·29	16·38	14·81	13·24	12·01	10·45	9·12	7·90	7·13	...	...	...	...
18·79	16·83	15·21	13·60	12·34	10·74	9·37	8·12	...	...	...	...	...
19·29	17·27	15·62	13·96	12·67	11·03	9·62	8·34	...	...	...	...	...
19·79	17·72	16·02	14·33	13·00	11·31	9·87	8·55	...	...	...	...	...
20·29	18·17	16·43	14·69	13·33	11·60	10·12	8·77	...	...	...	...	...
20·79	18·62	16·83	15·05	13·66	11·89	10·37	...	...	...	...	...	...
21·29	19·06	17·24	15·42	13·99	12·18	10·63	...	...	...	...	...	...
21·79	19·51	17·64	15·78	14·32	12·46	10·88	...	...	...	...	...	...
22·29	19·96	18·05	16·14	14·65	12·75	11·13	...	...	...	...	...	...
22·79	20·41	18·45	16·51	14·98	13·04	...	...	...	...	...	...	...
23·28	20·85	18·86	16·87	15·31	13·33	...	...	...	...	...	...	...
23·78	21·30	19·26	17·23	15·64	13·61	...	...	...	...	...	...	...
24·28	21·75	19·67	17·59	15·97	13·90	...	...	...	...	...	...	...
24·78	22·20	20·08	17·96	16·30	...	...	...	...	...	...	...	...
25·28	22·65	20·48	18·32	16·63	...	...	...	...	...	...	...	...
25·78	23·09	20·89	18·68	16·96	...	...	...	...	...	...	...	...
26·28	23·54	21·29	19·05	17·29	...	...	...	...	...	...	...	...
26·78	23·99	21·70	19·41	...	...	...	...	...	...	...	...	...
27·28	24·44	22·10	19·77	...	...	...	...	...	...	...	...	...
27·78	24·88	22·51	20·13	...	...	...	...	...	...	...	...	...
28·27	25·33	22·91	20·50	...	...	...	...	...	...	...	...	...
0·66	0·53	0·43	0·35	0·29	0·22	0·17	0·12	0·10	0·08	0·06	0·04	0·03

number given at bottom of column ; for example—The Weight 12 B. W. G., is 2·78 − 0·29 = 2·49lbs. *f*. full ; *b*, bare.

TABLE 163.—WEIGHT OF SEAMLESS BRASS TUBES 70% OF COPPER AND 30% OF ZINC. Specific gravity 8·558. (The Broughton Copper Company). IMPERIAL WIRE GAUGE 1884.

1884.		THICKNESS OF BRASS.															
I. W. G.		5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Inches.		0·212	0·192	0·176	0·160	0·144	0·128	0·116	0·104	0·092	0·080	0·072	0·064	0·056	0·048	0·040	0·036
		$\frac{7}{32}$ *b*	$\frac{3}{16}$·*f*	$\frac{11}{64}$·*f*	$\frac{5}{32}$·*f*	$\frac{9}{64}$·*f*	$\frac{1}{8}$·*f*	$\frac{7}{64}$·*f*	$\frac{7}{64}$ *b*	$\frac{3}{32}$	$\frac{5}{64}$·*f*	$\frac{5}{64}$ *b*	$\frac{1}{16}$ *f*	$\frac{1}{16}$ *b*	$\frac{3}{64}$·*f*	$\frac{3}{64}$ *b*	$\frac{1}{32}$·*f*
Millimetres.		5·385	4·877	4·470	4·064	3·658	3·251	2·946	2·642	2·337	2·032	1·829	1·626	1·422	1·219	1·016	0·914
External Diameter.		WEIGHT OF A LINEAL FOOT IN POUNDS.															
Inches.	Millim.																
$\frac{3}{8}$	9·5	...	...	...	...	...	...	...	...	...	...	...	...	0·21	0·18	0·16	0·14
$\frac{7}{16}$	11·1	...	...	...	...	...	...	...	...	...	...	...	0·28	0·25	0·22	0·18	0·17
$\frac{1}{2}$	12·7	...	...	...	...	...	...	...	...	...	...	0·36	0·32	0·29	0·25	0·21	0·19
$\frac{5}{8}$	15·9	...	...	...	...	...	...	...	...	...	0·51	0·46	0·42	0·37	0·32	0·27	0·25
$\frac{3}{4}$	19·0	...	...	...	...	...	...	...	...	0·70	0·62	0·57	0·51	0·45	0·39	0·33	0·30
$\frac{7}{8}$	22·2	...	...	...	...	...	...	...	0·93	0·84	0·74	0·67	0·60	0·53	0·46	0·39	0·35
1	25·4	...	...	...	...	...	...	1·19	1·08	0·97	0·86	0·78	0·70	0·62	0·53	0·45	0·40
1$\frac{1}{8}$	28·6	...	...	...	...	...	1·49	1·36	1·24	1·11	0·97	0·88	0·79	0·70	0·60	0·50	...
1$\frac{1}{4}$	31·7	...	...	...	...	...	1·67	1·53	1·39	1·24	1·09	0·99	0·88	0·78	0·67	0·56	...
1$\frac{3}{8}$	34·9	...	...	...	...	2·06	1·86	1·70	1·54	1·37	1·21	1·09	0·98	0·86	0·74	0·62	...
1$\frac{1}{2}$	38·1	...	...	...	...	2·27	2·04	1·87	1·69	1·51	1·32	1·20	1·07	0·94	0·81	0·68	...
1$\frac{5}{8}$	41·3	...	...	...	2·73	2·48	2·23	2·04	1·84	1·64	1·44	1·30	1·16	1·02	0·88	...	...
1$\frac{3}{4}$	44·4	...	...	...	2·96	2·69	2·42	2·21	1·99	1·78	1·56	1·41	1·26	1·10	0·95	...	...
1$\frac{7}{8}$	47·6	...	...	3·48	3·19	2·90	2·60	2·38	2·14	1·91	1·67	1·51	1·35	1·19	1·02	...	...
2	50·8	...	...	3·74	3·43	3·11	2·79	2·54	2·30	2·04	1·79	1·62	1·44	1·27	1·09	...	...
2$\frac{1}{8}$	54·0	...	4·32	3·99	3·66	3·32	2·98	2·71	2·45	2·18	1·90	1·72	1·54	1·35	...	...	...

2¼	57·1	...	4·60	4·25	3·89	3·53	3·16	2·88	2·60	2·31	2·02	1·83	1·63	1·43	...	...	...
2⅜	60·3	5·34	4·88	4·51	4·13	3·74	3·35	3·05	2·75	2·45	2·14	1·93	1·72	1·51	...	...	...
2½	63·5	5·65	5·16	4·76	4·36	3·95	3·54	3·22	2·90	2·58	2·25	2·04	1·81	1·59	...	...	...
2⅝	66·7	5·96	5·44	5·02	4·59	4·16	3·72	3·39	3·05	2·71	2·37	2·14	1·91	1·67	...	...	...
2¾	69·8	6·27	5·72	5·28	4·83	4·37	3·91	3·56	3·20	2·85	2·49	2·24	2·00	1·76	...	...	...
2⅞	73·0	6·57	6·00	5·53	5·06	4·58	4·09	3·73	3·36	2·98	2·60	2·35	2·09	1·84	...	...	...
3	76·2	6·88	6·28	5·79	5·29	4·79	4·28	3·90	3·51	3·11	2·72	2·45	2·19	1·92	...	...	...
3⅛	79·3	7·19	6·56	6·04	5·52	5·00	4·47	4·06	3·66	3·25	2·84	2·56	2·28	...	...	...	...
3¼	82·5	7·50	6·84	6·30	5·76	5·21	4·65	4·23	3·81	3·38	2·95	2·66	2·37	...	...	...	...
3⅜	85·7	7·81	7·12	6·56	5·99	5·42	4·84	4·40	3·96	3·52	3·07	2·77	2·47	...	...	...	...
3½	88·9	8·12	7·40	6·81	6·22	5·63	5·03	4·57	4·11	3·65	3·19	2·87	2·56	...	...	...	...
3⅝	92·0	8·43	7·68	7·07	6·46	5·84	5·21	4·74	4·26	3·78	3·30	2·98	2·65	...	...	...	...
3¾	95·2	8·73	7·95	7·32	6·69	6·05	5·40	4·91	4·42	3·92	3·42	3·08	2·75	...	...	...	...
3⅞	98·4	9·04	8·23	7·58	6·92	6·26	5·58	5·08	4·57	4·05	3·53	3·19	2·84	...	...	...	...
4	101·6	9·35	8·51	7·84	7·15	6·47	5·77	5·25	4·72	4·19	3·65	3·29	2·93	...	...	...	...
4¼	107·9	9·97	9·07	8·35	7·62	6·88	6·14	5·58	5·02	4·45	3·88	3·50	...	...	...	...	...
4½	114·3	10·59	9·63	8·86	8·09	7·30	6·52	5·92	5·32	4·72	4·12	3·71	...	...	...	...	...
4¾	120·6	11·20	10·19	9·37	8·55	7·72	6·89	6·26	5·63	4·99	4·35	...	...	...	...	...	...
5	127·0	11·82	10·75	9·89	9·02	8·14	7·26	6·60	5·93	5·26	4·58	...	...	...	...	...	...
5¼	133·3	12·44	11·31	10·40	9·48	8·56	7·63	6·93	6·23	5·53	...	...	...	...	...	...	...
5½	139·7	13·05	11·87	10·91	9·95	8·98	8·01	7·27	6·53	5·79	...	...	...	...	...	...	...
5¾	146·0	13·67	12·43	11·42	10·41	9·40	8·38	7·61	6·84	...	...	...	...	...	...	...	...
6	152·4	14·29	12·99	11·94	10·88	9·82	8·75	7·95	...	...	...	...	...	...	...	...	...
Per cent.		103·4	105·2	102·1	102·9	102·6	104·	103·3	104·6	103·1	103·6	100·0	101·5	103·5	102·0	104·8	97·3

Note.—The numbers at bottom show the relative Weights of Brass Tubes made to the B.W.G. and to the I.W.G. 1884, the latter being taken at 100.

The above weights, multiplied by 0·994, give corresponding weights of Brass Tubes 2 and 1 alloy.

TABLE 164.—WEIGHT OF SEAMLESS BRASS TUBES, CONTAINING 70 °/$_{\circ}$ OF COPPER AND 30 °/$_{\circ}$ OF ZINC (The Broughton Copper Company). BIRMINGHAM WIRE GAUGE.

		THICKNESS OF BRASS.															
B. W. G.		5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Inches.		0·220	0·203	0·180	0·165	0·148	0·134	0·120	0·109	0·095	0·083	0·072	0·065	0·056	0·049	0·042	0·035
		$\frac{7}{32}$ *f*	$\frac{13}{64}$	$\frac{3}{16}$ *b*	$\frac{11}{64}$ *b*	$\frac{9}{64}$ *f*	$\frac{9}{64}$ *b*	$\frac{1}{8}$ *b*	$\frac{7}{64}$	$\frac{3}{32}$ *f*	$\frac{5}{64}$ *f*	$\frac{5}{64}$ *b*	$\frac{1}{16}$ *f*	$\frac{1}{16}$ *b*	$\frac{3}{64}$ *f*	$\frac{3}{64}$ *b*	$\frac{1}{32}$ *f*
Millimetres.		5·59	5·16	4·57	4·19	3·76	3·40	3·05	2·77	2·41	2·11	1·83	1·65	1·47	1·24	1·07	0·89
External Diameter.		WEIGHT OF LINEAL FOOT IN POUNDS.															
Inches.	Millim.																
$\frac{3}{8}$	9·5	...	...	...	...	...	...	...	...	...	...	...	...	0·21	0·19	0·16	0·14
$\frac{7}{16}$	11·0	...	...	...	...	...	...	...	...	...	...	...	0·28	0·26	0·22	0·19	0·10
$\frac{1}{2}$	12·7	...	...	...	...	...	...	...	...	...	...	0·36	0·33	0·30	0·26	0·22	0·19
$\frac{5}{8}$	15·9	...	...	...	...	...	...	...	...	...	0·52	0·46	0·42	0·38	0·33	0·28	0·24
$\frac{3}{4}$	19·0	...	...	...	...	...	...	...	...	0·72	0·64	0·57	0·52	0·47	0·40	0·35	0·29
$\frac{7}{8}$	22·2	...	...	...	...	...	...	...	0·97	0·86	0·76	0·67	0·61	0·55	0·47	0·41	0·34
1	25·4	...	...	...	...	...	...	1·23	1·13	1·00	0·89	0·78	0·71	0·64	0·54	0·47	0·39
1$\frac{1}{8}$	28·6	...	...	...	...	...	1·55	1·40	1·29	1·14	1·01	0·88	0·80	0·72	0·61	0·53	...
1$\frac{1}{4}$	31·7	...	...	...	...	...	1·74	1·58	1·45	1·28	1·13	0·99	0·90	0·80	0·68	0·59	...
1$\frac{3}{8}$	34·9	...	...	...	...	2·11	1·94	1·75	1·61	1·42	1·25	1·09	0·99	0·89	0·76	...	...
1$\frac{1}{2}$	38·1	...	...	...	...	2·33	2·13	1·93	1·77	1·55	1·37	1·20	1·09	0·97	0·83	...	...
1$\frac{5}{8}$	41·3	...	...	...	2·80	2·55	2·33	2·10	1·92	1·69	1·49	1·30	1·18	1·06	...	...	...
1$\frac{3}{4}$	44·4	...	...	...	3·04	2·76	2·52	2·28	2·08	1·83	1·61	1·41	1·27	1·14	...	...	...
1$\frac{7}{8}$	47·6	...	...	3·55	3·29	2·98	2·72	2·45	2·24	1·97	1·73	1·51	1·37	1·23	...	...	...
2	50·8	...	...	3·81	3·53	3·19	2·91	2·63	2·40	2·11	1·85	1·62	1·46	1·31	...	...	...

2⅛	54·0	...	4·54	4·08	3·77	3·41	3·11	2·80	2·56	2·25	1·97	1·72	1·56	1·40	...	...	...
2¼	57·1	...	4·84	4·34	4·01	3·62	3·30	2·98	2·72	2·38	2·09	1·83	1·65	1·48	...	...	...
2⅜	60·3	5·52	5·13	4·60	4·25	3·84	3·50	3·15	2·88	2·52	2·21	1·93	1·75	1·56	...	...	...
2½	63·5	5·84	5·43	4·86	4·49	4·05	3·69	3·33	3·03	2·66	2·34	2·04	1·84	1·65	...	...	...
2⅝	66·7	6·16	5·73	5·12	4·73	4·27	3·89	3·50	3·19	2·80	2·46	2·14	1·94	...	...	...	...
2¾	69·8	6·48	6·02	5·39	4·97	4·48	4·08	3·67	3·35	2·94	2·58	2·24	2·03	...	...	...	...
2⅞	73·0	6·80	6·32	5·65	5·21	4·70	4·28	3·85	3·51	3·07	2·70	2·35	2·13	...	...	...	...
3	76·2	7·12	6·61	5·91	5·45	4·91	4·47	4·02	3·67	3·21	2·82	2·45	2·22	...	...	...	...
3⅛	79·3	7·44	6·91	6·17	5·69	5·13	4·67	4·20	3·83	3·35	2·94	2·56	2·32	...	...	...	...
3¼	82·5	7·76	7·20	6·43	5·93	5·35	4·86	4·37	3·99	3·49	3·06	2·66	2·41	...	...	...	...
3⅜	85·7	8·08	7·50	6·70	6·17	5·56	5·06	4·55	4·15	3·63	3·18	2·77	2·50	...	...	...	...
3½	88·9	8·40	7·79	6·96	6·41	5·78	5·25	4·72	4·30	3·77	3·30	2·87	2·60	..	...	...	...
3⅝	92·0	8·72	8·09	7·22	6·65	5·99	5·45	4·90	4·46	3·90	3·42	2·98	2·69	...	...	...	...
3¾	95·2	9·04	8·38	7·48	6·89	6·21	5·64	5·07	4·62	4·04	3·54	3·08	2·79	...	...	...	...
3⅞	98·4	9·36	8·68	7·74	7·13	6·42	5·84	5·25	4·78	4·18	3·66	3·19	2·88	...	...	...	...
4	101·6	9·68	8·98	8·01	7·37	6·64	6·03	5·42	4·94	4·32	3·79	3·29	2·98	...	...	...	...
		1·12	0·96	0·74	0·64	0·50	0·41	0·33	0 27	0·21	0·16	0·12	0·10	0·08	0·06	0·05	0·03

Note.—If the internal diameter is given, add figure at bottom of Column; for example—The weight per lineal foot of a Brass Tube 2ins. internal diameter, 12 B. W. G. is 2·40 + 0·27 = 2·67lb. *f*, full; *b*, bare.

W. G. .	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Percentage	96·6	94·8	97·1	97·1	97·4	95·6	96·7	95·4	96·9	96·4	100·0	98·5	96·5	98·0	95·2	102·7

Note.—These numbers show the relative weights of Brass Tubes made to the Imperial Wire Gauge, 1884, and the Birmingham Wire Gauge, the latter being taken at 100.

TABLE 165.—COPPER NAILS AND RIVETS: SIZE AND WEIGHT.

Description.	Gauge.	Length.	Weight per 1,000.	
	No.	Inches.	Lb.	Oz.
Copper nails, wrought, clench, flat-head, full countersunk	13	1	2	9
	13	1⅛	2	15
,,	12	1¼	4	8
,,	11	1½	6	6
,,	13	1¾	4	12
,,	11	1¾	7	8
,,	11	2	8	8
,,	10	2¼	12	12
,,	11	2⅜	10	0
,,	11	2½	10	10
,,	9	2½	17	12
,,	9	2¾	19	4
,,	8	3	25	8
,,	8	3¼	28	0
,,	8	3½	29	12
,,	7	3¾	36	0
,,	6	4	48	8
,,	6	4½	55	4
,,	4	5	82	12
,,	3	5½	108	0
,,	3	6	119	0
,,	4	6	107	12
,,	3	7	136	12
,,	3	7½	146	4
,,	2	8	189	0
,,	2	8½	199	0
Spike die-heads, with flat points	12	1½	4	12
,, ,,	10	1¾	9	8
,, ,,	9	2	12	0
,, ,,	7	2½	19	10
,, ,,	6	3	30	0
,, ,,	4	3½	48	0
,, ,,	2	4½	84	8
Rose-heads, with flat points	14	¾	1	9
,, ,,	13	1	2	4
,, ,,	13	1¼	3	0
,, ,,	12	1½	4	6
,, ,,	10	1¾	9	8
,, ,,	10	2	10	12

TABLE 165.—COPPER NAILS AND RIVETS (*continued*).

Description.	Gauge.	Length.	Weight per 1,000.	
	No.	Inches.	Lb.	Oz.
Rose-heads, with flat points	8	2¼	16	14
" "	8	2½	19	8
" "	6	3	30	0
" "	5	3½	42	8
" "	4	4	53	12
" "	3	4½	71	0
" "	2	5	93	0
Clasp	...	2½	13	0
"	...	2	9	0
"	...	1½	4	0
"	...	1¼	2	10
"	...	1	1	12
"	...	1½	...	
Cut copper nails, brads, billed	...	⅝	0	10
" "	...	¾	0	12
" "	...	1	1	10
" "	...	1¼	2	4
" "	...	1½	3	12
" "	...	1¾	5	8
Lightning conductor, countersunk heads, and flat points, jagged	6	1½	10	8
	5	1¾	15	0
"	4	2	18	8
"	3	2¼	26	0
"	1	2½	40	0
"	1	3	52	0
Scarf tacks, square flat-heads, with sharp points	16	½	0	9
	16	...	0	11
"	16	¾	1	1
"	15	⅞	1	6
Slating	...	1½	...	
Coppersmith's rivets, flat pan-head	2	⅞	22	4
" "	4	⅝	18	12
" "	6	6/8	9	12
" "	7	½	6	14
" "	10	⅜	3	0
" "	11	5/16	2	4
" "	12	¼	1	4
	Inches.			
" snap-heads	½	1¼	118	0
" "	7/16	1¼	91	0
" "	7/16	1	78	0
" "	½	1	102	0
" "	⅜	⅞	55	0
" "	⅜	1¼	71	0

TABLE 165.—COPPER NAILS AND RIVETS (*continued*).

Description.	Gauge.	Length.	Weight per 1,000.	
	No.	Inches.	Lb.	Oz.
Coppersmith's rivets, tinned for hoses—				
,, hose No. 1 .	8	$\frac{3}{8}$	4	8
,, hose No. 2 .	7	$\frac{7}{16}$	5	12
,, hose No. 3 .	7	8	6	8
,, hose No. 4 .	7	9	7	4
,, hose No. 4 .	7	11	8	4
,, washers for do.—				
,, hose No. 1 .	...	...	2	4
,, hose No. 2 .	...	...	2	12
,, hose No. 3 .	...	...	2	12
,, hose No. 4 .	...	...	3	4

Brazed Copper tubes weigh more per lineal foot than seamless tubes. An exact general multiple cannot be given, as the proportion of difference varies with the thickness, the diameter, and the kind of brazed joint.

Mandrel-drawn brazed Copper tubes weigh the same as Seamless tubes.

TABLE 166.—SHEET LEAD: WEIGHT PER SQUARE FOOT.

Usual size of Sheets, 32 feet × 7 feet.

Weight per Square Foot.	Thickness.	Weight per Square Foot.	Thickness.
Pounds.	Inch.	Pounds.	Inch.
2½	·042 or $\frac{1}{24}$	5½	·093 or $\frac{1}{11}$ full
3	·051 or $\frac{1}{20}$ full	6	·101 or $\frac{1}{10}$
3½	·059	6½	·110 or $\frac{1}{9}$
4	·067 or $\frac{1}{15}$ full	7	·118 or $\frac{2}{17}$
4½	·076 or $\frac{1}{13}$	7½	·126 or $\frac{1}{8}$ bare
5	·084 or $\frac{1}{12}$ full	8	·135 or $\frac{2}{15}$ full

TABLE 167.—SHEET LEAD. FRENCH PRACTICE.

Usual size of sheets, 2·80 metres and 3·88 metres wide, 8 to 10 metres long (9 feet 2 inches and 12 feet 9 inches wide, 26 feet to 33 feet long).

Thickness.	Weight per Square Metre.	Thickness.	Weight per Square Metre.
Millimetres.	Kilogrs. or Lbs.	Millimetres.	Kilogrs. or Lbs.
1	11·25 or 24·8	3	34·00 or 75·0
1½	17·00 or 37·5	4	45·40 or 100·1
2	22·70 or 50·1	5	56·80 or 125·2
2½	28·40 or 62·6	7	79·50 or 175·3

TABLE 168.—SOLID DRAWN LEAD PIPES: LENGTH AND WEIGHT.

(Walkers, Parker & Co.)

Bore.	Length.	Weights of One Length for Various Thicknesses.
Inches.	Feet.	Pounds.
3/16	15	15
1/4	15	10, 15, 20
3/8	15	10, 15, 20, 25
1/2	15	14, 15, 16, 18, 20, 22, 25, 27, 30, 35
9/16	15	16, 18, 20, 22
5/8	15	17, 21, 25, 30, 35, 40, 45
3/4	15	22, 24, 26, 28, 32, 36, 40, 45, 50, 55
7/8	15	28, 36
1	15	30, 36, 42, 45, 48, 52, 56, 60, 64, 70
1 1/8	15	42, 52, 60, 68, 76
1 1/4	12	28, 36, 42, 48, 52, 60, 64
1 1/2	12	28, 36, 48, 56, 60, 72, 84, 96
1 3/4	12	60, 72, 84, 96
2	12	36, 56, 72, 84, 96, 112, 120
2 1/4	12	100, 132
2 1/2	10	60, 70, 84, 96, 112, 120
2 3/4	10	100
3	10	100, 112, 120, 130, 140, 150
3 1/2	10	112, 130, 150, 160, 180
4	10	140, 160, 170, 200, 220
4 1/2	10	140, 170, 220
5	10	150, 220, 250
5 1/2	10	220
6	10	220
		DRAWN SOIL PIPE.
2 1/2	10	36, 45, 60, 70
3	10	45, 53, 60, 68, 74, 80
3 1/2	10	52, 60, 70, 90
4	10	56, 60, 70, 80, 100, 112
4 1/2	10	70, 80, 90, 100, 112
5	10	75, 88, 100, 112
5 1/2	10	90, 106
6	10	90, 106

TABLE 168.—SOLID DRAWN LEAD PIPES (*continued*).

DRAWN SQUARE SOIL PIPE.

Bore.	Length.	Weights of One Length for Various Thicknesses.
Inches.	Feet.	Pounds.
$3\frac{1}{2}\times3\frac{1}{2}$	10	60, 80
4×3	10	80, 100

COMPOSITION PIPE (Lead and Tin).

Diameters, inches	$\frac{1}{8}$, $\frac{3}{16}$, $\frac{1}{4}$, $\frac{5}{16}$, $\frac{3}{8}$, $\frac{7}{16}$,	About $\frac{1}{2}$ cwt. each coil.
Average length of coils, feet	670, 240, 220, 170, 150, 120,	
Diameters, inches	$\frac{1}{2}$, $\frac{9}{16}$, $\frac{5}{8}$, $\frac{3}{4}$, $\frac{7}{8}$, 1, $1\frac{1}{4}$	
Average length of coils, feet	100, 90, 70, 70, 60, 50, 40	

TABLE 169.—TIN PLATES: DIMENSIONS AND WEIGHTS.

Description.	Mark.	Dimensions of Sheets.	Number of Sheets in a Box.	Weight of each Box.
		Inches.	Sheets.	Pounds.
Common No. 1	IC	14×10	225	108
Cross No. 1	IX	14×10	225	136
Two crosses No. 1	IXX	14×10	225	157
Three crosses No. 1	IXXX	14×10	225	178
Four crosses No. 1	IXXXX	14×10	225	199
Common No. 1	IC	14×20	112	108
Cross No. 1	IX	14×20	112	136
Two crosses No. 1	IXX	14×20	112	157
Three crosses No. 1	IXXX	14×20	112	178
Four crosses No. 1	IXXXX	14×20	112	199
Common No. 1	IC	28×20	56	108
Cross No. 1	IX	28×20	56	136
Two crosses No. 1	IXX	28×20	56	157
Three crosses No. 1	IXXX	28×20	56	178
Four crosses No. 1	IXXXX	28×20	56	199
Common No. 1	IC	12×12	225	108
Cross No. 1	IX	12×12	225	136
Two crosses No. 1	IXX	12×12	225	157
Three crosses No. 1	IXXX	12×12	225	178

TABLE 169.—TIN PLATES: DIMENSIONS AND WEIGHTS (*continued*).

Description.	Mark.	Dimensions of Sheets.	Number of Sheets in a Box.	Weight of each Box.
		Inches.	Sheets.	Pounds.
Four crosses No. 1 . .	IXXXX	12×12	225	199
Common doubles . .	DC	17×12½	100	94
Cross doubles . . .	DX	17×12½	100	122
Two cross doubles . .	DXX	17×12½	100	143
Three cross doubles . .	DXXX	17×12½	100	164
Four cross doubles .	DXXXX	17×12½	100	185
Common doubles . .	DC	17×25	50	94
Cross doubles . .	DX	17×25	50	122
Two cross doubles . .	DXX	17×25	50	143
Three cross doubles .	DXXX	17×25	50	164
Four cross doubles . .	DXXXX	17×25	50	185
Common doubles . . .	DC	34×25	25	94
Cross doubles . . .	DX	34×25	25	122
Two cross doubles . .	DXX	34×25	25	143
Three cross doubles . .	DXXX	34×25	25	164
Four cross doubles .	DXXXX	34×25	25	185
Small common doubles .	SDC	15×11	200	167
Small cross doubles . .	SDX	15×11	200	188
Small two cross doubles.	SDXX	15×11	200	209
Small three cross doubles	SDXXX	15×11	200	230
Small four cross doubles	SDXXXX	15×11	200	251
Small common doubles .	SDC	15×22	100	167
Small cross doubles . .	SDX	15×22	100	188
Small two cross doubles.	SDXX	15×22	100	209
Small three cross doubles	SDXXX	15×22	100	230
Small four cross doubles	SDXXXX	15×22	100	251

Note.—The weights of the cross-marked boxes advance at the rate of 21 pounds per Cross.

TABLE 170.—BLOCK TIN PIPES: WEIGHT PER YARD.

Bore	$\frac{1}{4}$,	$\frac{5}{16}$,	$\frac{3}{8}$,	$\frac{7}{16}$,	$\frac{1}{2}$,	$\frac{5}{8}$,	$\frac{3}{4}$,	$\frac{7}{8}$,	1	inch.
Weight . . .	7,	9,	11,	14,	17,	23,	30,	38,	48	ounces.

TABLE 171.—ZINC SHEETS: ACCORDING TO THE V.M. ZINC GAUGE.

(Vielle-Montagne Company.)

V. M. Gauge.	Approximate Thickness.		Approximate Weight per Square Foot.			36 in. × 72 in.				36 in. × 84 in.				36 in. × 96 in.			
						Approximate Weight of Sheets.			Sheets per 500 Kilos, or 1102⅜ Lbs. English, about	Approximate Weight of Sheets.			Sheets per 500 Kilos, or 1102⅜ Lbs. English, about	Approximate Weight of Sheets.			Sheets per 500 Kilos, or 1102⅜ Lbs. English, about
	Thousandths of an Inch.	Metric Equivalent in Thousandths of a Millimetre.	Pounds.	Ounces.	Drachms.	Pounds.	Ounces.	Drachms.		Pounds.	Ounces.	Drachms.		Pounds.	Ounces.	Drachms.	
1	0·004	0.100	...	2	5	Nos. 1 and 2 are only rolled to order and special dimensions.											
2	·006	·141	...	3	4												
3	·007	·171	...	3	15	4	6	14	249	5	2	11	218	5	14	8	187
4	·008	·209	...	4	13	5	6	10	204	6	5	1	175	7	3	8	153
5	·010	·247	...	5	11	6	6	6	172	7	7	7	147	8	8	8	129
6	·011	·291	...	6	11	7	8	6	146	8	12	7	126	10	...	8	110
7	·013	·337	...	7	12	8	11	8	126	10	2	12	108	11	10	...	95
8	·015	·386	...	8	14	9	15	12	110	11	10	6	95	13	5	...	83
9	·018	·450	...	10	5	11	9	10	95	13	8	9	81	15	7	8	71
10	·020	·500	...	11	7	12	13	14	86	15	...	3	73	17	2	8	64
11	·023	·580	...	13	5	14	15	10	74	17	7	9	63	19	15	8	55
12	·026	·660	...	15	2	17	0	4	65	19	13	10	56	22	11	...	49
13	·029	·740	1	...	15	19	0	14	57	22	3	11	50	25	6	8	43
14	·032	·820	1	2	12	21	1	8	52	24	9	12	45	28	2	...	39
15	·038	·950	1	5	12	24	7	8	45	28	8	12	39	32	10	...	34
16	·043	1·080	1	8	12	27	13	8	39	32	7	12	34	37	2	...	30
17	·048	1·210	1	11	11	31	2	6	35	36	5	7	30	41	8	8	27
18	·053	1·340	1	14	11	34	8	6	31	40	4	7	27	46	...	8	24
19	·058	1·470	2	1	11	37	14	6	29	44	3	7	25	50	6	8	22
20	·063	1·600	2	4	10	41	3	4	27	48	1	2	23	54	15	...	20
21	·070	1·780	2	8	12	45	13	8	24	53	7	12	21	61	2	...	18
22	·077	1·960	2	12	14	50	7	12	22	58	14	6	19	67	5	...	16
23	·084	2·140	3	1	1	55	3	2	20	64	6	5	17	73	9	8	15
24	·091	2·320	3	5	3	59	13	6	18	69	12	15	16	79	12	8	14
25	·098	2·500	3	9	5	64	7	10	17	75	8	9	15	85	15	8	13
26	·105	2·680	3	13	7	69	1	14	16	80	10	3	14	92	2	8	12

TABLE 172.—ZINC SHEETS: ACCORDING TO THE ENGLISH ZINC GAUGE.

(London Zinc Mills.)

Gauge No.	Approximate Weight per Square Foot.	Thousandths of an Inch.	7 ft. × 2 ft. 8 in.		7 ft. × 3 ft.		8 ft. × 3 ft.		Nearest Birmingham Wire Gauge.
			Approximate		Approximate		Approximate		
			Weight per Sheet.	Number of Sheets in 10 Cwt.	Weight per Sheet.	Number of Sheets in 10 Cwt.	Weight per Sheet.	Number of Sheets in 10 Cwt.	
	Oz.		Lbs. Oz.		Lbs. Oz.		Lbs. Oz.		
1	2¼	·004	2 10	427	...	...	...	...	41
2	3¼	·006	3 13	294	...	...	...	...	38
3	3¾	·007	...	...	4 15	227	...	...	37
4	4¾	·008	...	...	6 4	180	...	...	34
5	5¾	·010	...	...	7 9	148	...	...	31
6	6¾	·011	7 14	142	8 14	126	10 2	111	30
7	7¾	·013	9 1	124	10 3	110	11 10	96	29
8	9	·015	10 8	107	11 13	95	13 8	83	28
9	10	·017	11 11	96	13 2	85	15 0	75	27
10	11½	·019	13 7	83	15 2	74	17 4	65	25
11	13	·021	15 3	74	17 1	66	19 8	57	24
12	15	·025	17 8	64	19 11	57	22 8	50	23
13	17	·028	...	...	22 5	50	25 8	44	22
14	19	·031	...	..	24 15	45	28 8	39	21
15	22	·036	...	...	28 14	39	33 0	34	20
16	25	·041	...	...	32 13	34	37 8	30	19
17	28	·046	...	...	36 12	30	42 0	27	18
18	31	·051	...	...	40 11	28	46 8	24	...
19	35	·059	...	...	45 15	24	52 8	21	17
20	39	·065	...	...	51 3	22	58 8	19	16
21	43	·072	...	...	56 7	20	64 8	17	15

Sheets thicker than above are rolled to Birmingham Wire Gauge.

WIRE ROPES. *See* STRENGTH OF MATERIALS (pp. 386—400).

CHAINS AND CHAIN CABLES. *See* STRENGTH OF MATERIALS (pp. 400—408).

STRENGTH OF MATERIALS.

Strength of Beams.

The ultimate transverse strength of a cantilever or homogeneous beam of uniform square or rectangular section, fixed at one end and loaded at the other end, is usually expressed by the formula,—

$$W = \frac{bd^2s}{6l} \quad \text{or} \quad \frac{1{\cdot}6667bd^2s}{l}$$

W = breaking weight at the end of the beam.
b = breadth of the beam in inches.
d = depth of the beam in inches.
l = length of the beam, between the fixed point and the load, in inches; or the distance apart of two supports.
s = ultimate tensile strength of the beam per square inch.

This formula, it is known, is materially defective, in understating the actual strength.

The correct formula is :—

1. *Beam fixed at one end, loaded at the other end.*

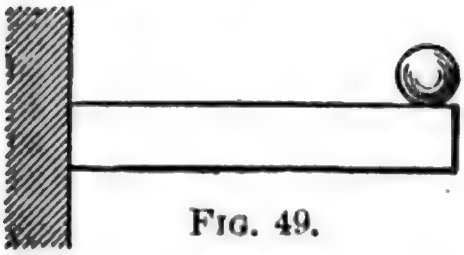


FIG. 49.

$$W = \frac{bd^2s}{3{\cdot}43l}, \quad \text{or} \quad \frac{{\cdot}292bd^2s}{l} \quad . \quad . \quad . \quad . \quad (1)$$

$$s = \frac{3{\cdot}43Wl}{bd^2}, \quad \text{or} \quad \frac{Wl}{{\cdot}292bd^2} \quad . \quad . \quad . \quad . \quad . \quad (2)$$

A beam freely supported at both ends, and loaded at the middle, bears four times the breaking weight of the cantilever :—

2. *Beam supported at both ends, loaded at the middle.*

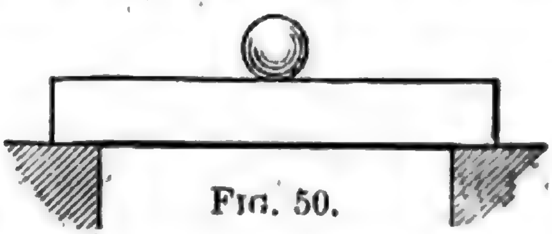


FIG. 50.

$$W = \frac{1{\cdot}167bd^2s}{l} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

$$s = \frac{Wl}{1{\cdot}167bd^2} \tag{4}$$

A beam fixed at each end, and loaded at the middle, bears eight times the breaking weight of the cantilever :—

3. *Beam fixed at each end, loaded at the middle.*

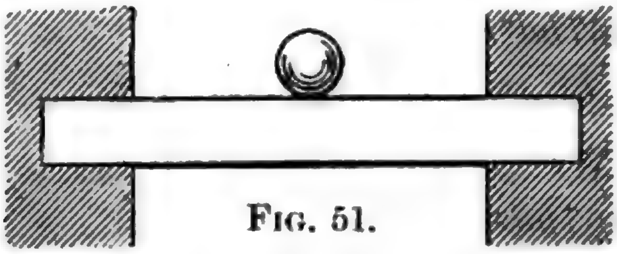


FIG. 51.

$$W = \frac{2{\cdot}333bd^2s}{l} \tag{5}$$

$$s = \frac{Wl}{2{\cdot}333bd^2} \tag{6}$$

Beams on which the load is equally distributed, are capable of a breaking weight double the central load given in the foregoing formulæ :—

4. *Beam fixed at one end, and uniformly loaded.*

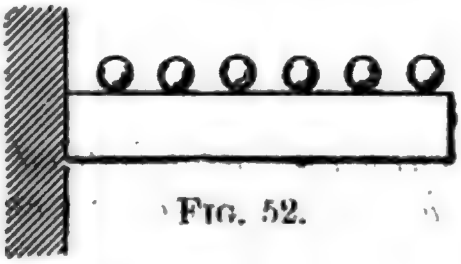


FIG. 52.

$$W = \frac{{\cdot}583bd^2s}{l} \tag{7}$$

$$s = \frac{Wl}{{\cdot}583bd^2} \tag{8}$$

5. *Beam supported at both ends, uniformly loaded.*

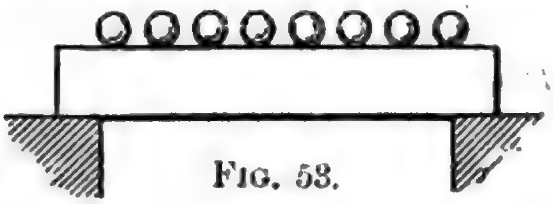


FIG. 53.

$$W = \frac{2{\cdot}333bd^2s}{l} \tag{9}$$

$$s = \frac{Wl}{2{\cdot}333bd^2} \tag{10}$$

6. *Beam fixed at each end, uniformly loaded.*

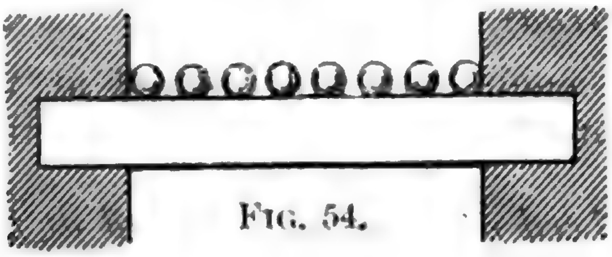


FIG. 54.

$$W = \frac{4{\cdot}667bd^2s}{l} \qquad . \quad . \quad . \quad . \quad . \quad . \quad (11)$$

$$s = \frac{Wl}{4{\cdot}667bd^2} \qquad . \quad . \quad . \quad . \quad . \quad . \quad (12)$$

When a concentrated load is applied elsewhere than at the middle of a beam, the breaking weight is inversely proportional to the product mn of the segments m and n into which the beam is divided by the load. The product when the load is at the centre is $(\frac{1}{2}\,l)^2$, and the formula (3), for a beam supported at both ends, becomes—

7. *Beam supported at both ends and loaded at a point between the middle and one end.*

$$W = \frac{1{\cdot}167bd^2ls}{mn} \qquad . \quad . \quad . \quad . \quad . \quad . \quad (13)$$

In like manner—

8. *Beam fixed at each end, and loaded at a point between the middle and one end.*

$$W = \frac{2{\cdot}333bd^2ls}{mn} \qquad . \quad . \quad . \quad . \quad . \quad . \quad (14)$$

The breaking weight of a homogeneous beam of uniform square section, of which one diagonal is vertical, supported at both ends, is expressed by the formula—

9. *Square beam supported at both ends, loaded at the centre; one of the diagonals vertical.*

$$W = \frac{{\cdot}943b^3s}{l} \qquad . \quad . \quad . \quad . \quad . \quad . \quad (15)$$

showing that the diagonally placed square beam has only about 81 per cent. of the strength of the square set beam, formula (3).

The breaking weight of a homogeneous uniform cylindrical beam, supported at both ends, is given by the formula—

10. *Cylindrical beam supported at both ends, loaded at the centre.*

$$W = \frac{\cdot 726 d^3 s}{l} \qquad (16)$$

It is deducible that the transverse strength of a cylindrical beam is only 90 per cent. of that of a square beam, laid square, of the same sectional area.

The breaking weight of a homogeneous uniform beam of elliptical section, laid with either axis vertical, is as follows :—

11. *Beam of elliptical section, supported at both ends, laid with one axis vertical.*

$$W = \frac{\cdot 726 b d^2 s}{l} \qquad (17)$$

in which b is the length of the horizontal axis, and d is that of the vertical axis.

The strength of equal flanged or hollow beams may be calculated by the formula :—

Symmetrical flanged or hollow beam. General formula.

$$W = \frac{d'' s (4a + 1{\cdot}167 a'')}{l} \qquad (18)$$

a = the sectional area of one flange, in square inches.
a'' = the area of the vertical web, or webs, in square inches, the reputed vertical height of the web being taken, for calculation, equal to the depth of the beam minus the thickness of one flange.
d'' = the reputed depth, equal to that of the web.
s = the ultimate tensile strength in tons per square inch.
l = the span in inches.
W = the breaking load in tons at the centre.

For the strength of cast-iron flange beams, the following formula is applicable in which the tensile strength is taken as 7 tons per square inch :—

Ultimate transverse strength of cast-iron beams.

$$W = \frac{d''(7a + 2a'')}{3l} \qquad (19)$$

W = breaking weight in tons at the middle.
a = sectional area of the lower flange, square inches.
a'' = sectional area of the web, taken at the reputed depth (total depth minus thickness of lower flange), square inches.
l = span in feet.

For various tensile strengths per square inch, the following are the constants to be employed in the formula:—

Tons per Square Inch.	Constants in formula (19) for a	for a''.
6	6	1·7
6¾	6¾	1·9
7	7	2·0
7½	7½	2·2
8	8	2·3
9	9	2·6
10	10	2·9

Ultimate transverse strength of solid rolled joists, of wrought iron (approximate).

$$W = \frac{7d(a + \frac{1}{4}a'')}{l} \quad \ldots \quad (20)$$

Note.—The sectional area of the web (a'') is, in this case, taken for the whole depth of the joist.

2. The ultimate tensile strength of the metal is taken at 20 tons per square inch.

3. For iron or steel of other than 20 tons tensile strength per square inch, substitute ⅓rd of the other tensile strength, for the constant 7 in the formula.

Ultimate transverse strength of riveted wrought-iron girders (approximate).

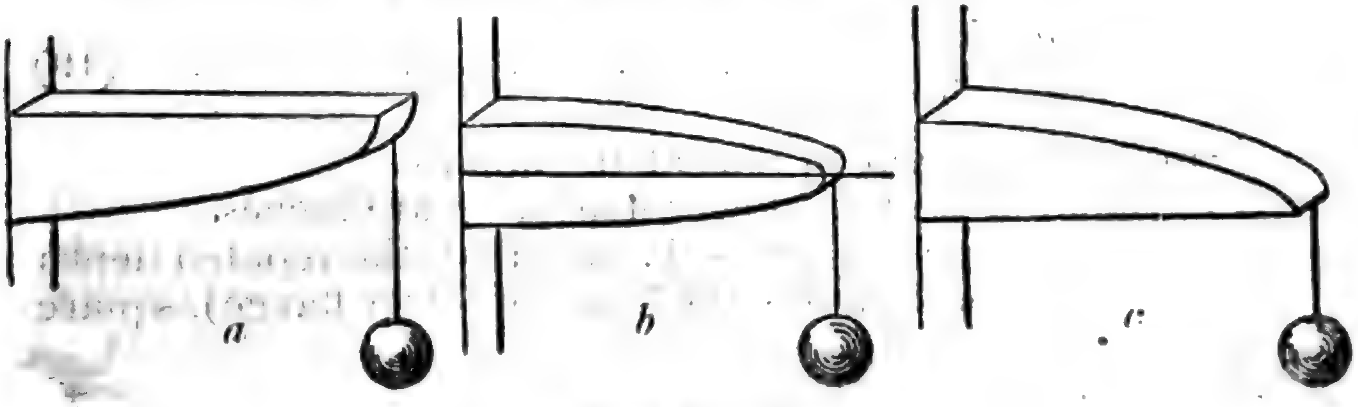
$$W = \frac{4\frac{2}{3}d(a' + \frac{1}{4}a'')}{l} \quad \ldots \quad (21)$$

Cantilevers and Beams of Uniform Strength.

The basic forms, exclusive of provision for shearing resistance, are as follows:—

1. *Cantilevers of uniform transverse strength, loaded at one end.*

1. When a cantilever is rectangular in section, it may be of either of the parabolic forms *a*, *b*, *c*, figs. 55—57.



Figs. 55—57.

2. When the section, fig. 58, is rectangular and the depth is constant, the breadth is in proportion to the distance from the end of the beam, and the beam is triangular in plan.

3. When the section is double-flanged, as in fig. 59, or hollow rectangular, and the breadth uniform, the form of the beam, in side elevation, is triangular, supposing that the resistance of the web is not calculated.

4. A double-flanged semi-beam, fig. 60, or hollow beam rectangular in section, of uniform depth, is triangular in plan, when calculated for the flanges only.

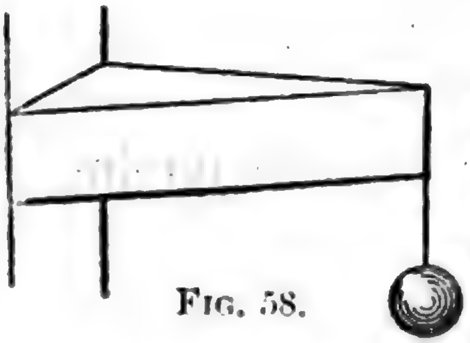


FIG. 58.

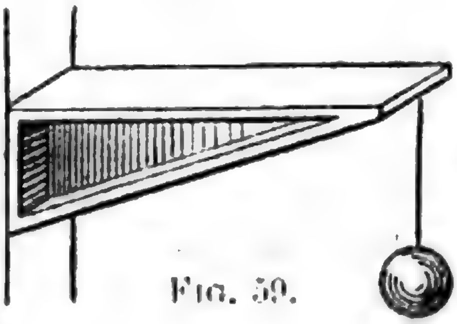


FIG. 59.

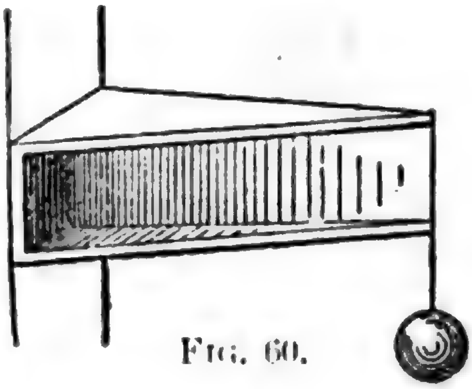


FIG. 60.

5. When the section of the semi-beam is circular, the outline is formed by the revolution of a cubic parabola on its axis, fig. 61.

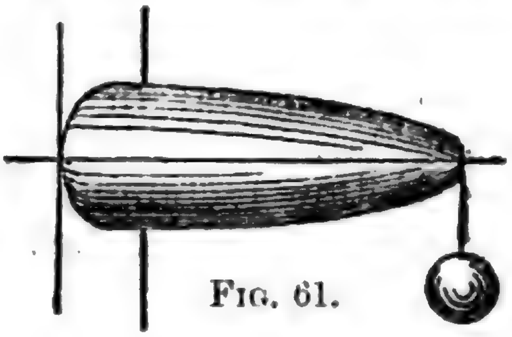


FIG. 61.

6. When the section of the semi-beam is annular, the form is generated by the revolution of a parabola on its axis. If the thickness varies with the diameter, the semi-beam is cubic-parabolic.

2. *Cantilevers of uniform strength, uniformly loaded.*

1. Rectangular in section, breadth uniform, triangular in side elevation, fig. 62.

2. Rectangular in section, depth uniform, breadth parabolic, fig. 63.

3. Hollow rectangular, or double-flanged, breadth uniform, depth parabolic, not reckoning webs, fig. 64.

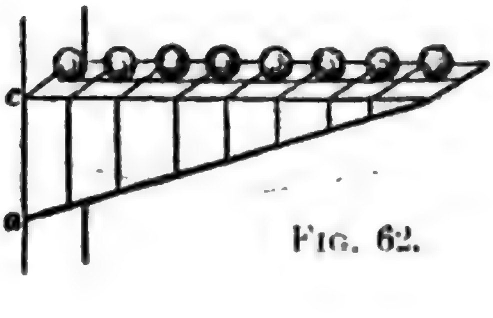


FIG. 62.

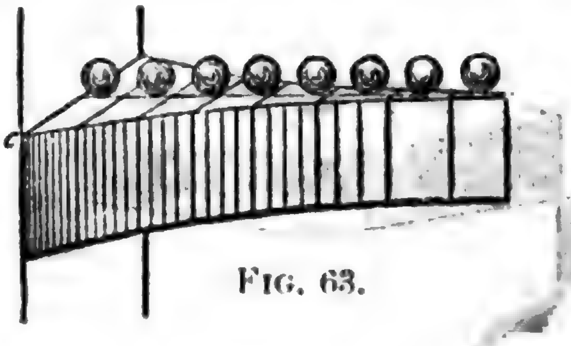


FIG. 63.

4. Hollow rectangular, or double-flanged, depth uniform, breadth parabolic, fig. 65.

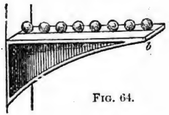


FIG. 64.

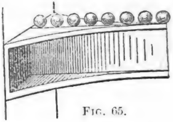


FIG. 65.

5. Section circular. The form is generated by the revolution of a semi-cubic parabola on its axis.

6. Section annular, conical form.

3. *Beams of uniform strength, loaded at the middle.*

1. Rectangular in section, breadth uniform, depth double-parabolic.

2. Rectangular in section, depth uniform, breadth double-triangular.

3. Hollow rectangular or double-flanged, breadth uniform. depth double-triangular, figs. 66, 67.

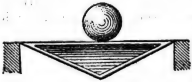


FIG. 66.

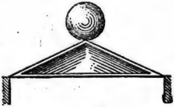


FIG. 67.

4. Hollow rectangular or double-flanged, depth uniform, breadth double-triangular, fig. 68.

5. Circular section ; form double-parabolic, fig. 69.

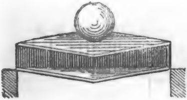


FIG. 68

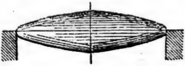


FIG. 69.

4. *Beams of uniform strength, uniformly loaded.*

1. Rectangular section, breadth uniform, depth elliptical.
2. Rectangular section, depth uniform, breadth double-parabolic; two parabolas having their vertices at the middle, and meeting at the points of support.
3. Hollow rectangular or double-flanged, breadth uniform, depth parabolic, fig. 70.
4. Hollow rectangular or double-flanged, depth uniform, breadth double-parabolic, fig. 71.

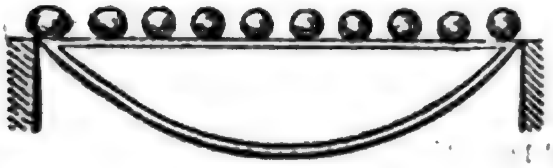


FIG. 70.

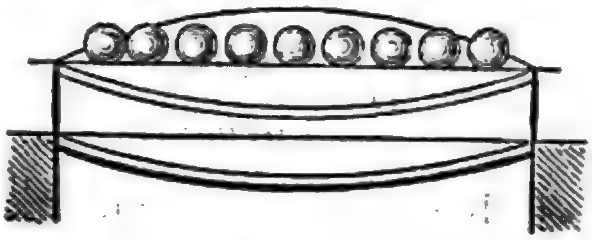


FIG. 71.

Approximate Deflection of Beams.

In a beam of uniform depth and uniform strength, the form assumed under the load is that of a circular arc.

Let l = length of the span, or distance between the supports.
b = breadth of the beam at the middle.
d = depth of the beam at the middle.
E = coefficient of elasticity, or the denominator of the fraction of the length by which the beam is extended or compressed per ton of direct stress per square inch of section.
D = deflection of beam, at middle.

Deflection of Beams of Rectangular Section, supported at each End.

1. Rectangular section, of uniform strength, depth uniform, double-triangular in plan, load at the middle :—

$$D = \frac{Wl^3}{4{\cdot}67bd^3E} \quad . \quad . \quad . \quad . \quad . \quad . \quad (22)$$

This formula signifies that the deflection varies directly as the weight, and as the cube of the span; and that it varies inversely as the breadth, and as the cube of the depth, and as the coefficient of elasticity.

2. Rectangular beam, of uniform strength, breadth uniform, depth parabolic; load at the middle.

$$D = \frac{Wl^3}{3{\cdot}11bd^3E} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (23)$$

3. Rectangular beam, of uniform section; load at the middle.

$$D = \frac{Wl^3}{4{\cdot}67bd^3E} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (24)$$

4. Rectangular beam, of uniform strength; depth uniform, uniformly loaded.

$$D = \frac{Wl^3}{9{\cdot}33bd^3E} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (25)$$

5. Rectangular beam, of uniform strength, breadth uniform; elliptic in depth; uniformly loaded.

$$D = \frac{Wl^3}{7{\cdot}47bd^3E} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (26)$$

6. Rectangular beam, of uniform section; uniformly loaded.

$$D = \frac{Wl^3}{7{\cdot}47bd^3E} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (27)$$

Deflection of Double-flanged or Hollow-Rectangular Beams: Equal Flanges.

7. Double-flanged beam, of uniform strength; uniform depth, double-triangular in breadth; load at the middle.

Case 1. When the strength of both the flanges and the web is calculated:—

$$D = \frac{Wl^3}{4d''^2E(4a + 1{\cdot}167a'')} \quad . \quad . \quad . \quad . \quad . \qquad (28)$$

d'' = distance apart between centres of flanges.
a = sectional area of one flange.
a'' = sectional area of the web, reckoned equal in height to d''.

From this equation it is inferred that the deflection varies inversely as a power of the depth greater than the square, and less than the cube.

Case 2. When the strength of the flanges alone is calculated:—

$$D = \frac{Wl^3}{16ad''^2E} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (29)$$

8. Double-flange beam, of uniform strength, of uniform breadth, triangular in depth; loaded at the middle (figs. 66, 67).

Case 1. When the strength of both the flanges and the web is calculated :—

$$D = \frac{Wl^3}{2d''^2E(4a + 1\cdot167a'')} \quad . \quad . \quad . \quad . \quad (30)$$

Case 2. When the strength of the flanges alone is calculated :—

$$D = \frac{Wl^3}{8ad''^2E} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (31)$$

9. Double-flange beam, of uniform section, loaded at the middle. See No. 7, formulæ 28 and 29.

10. Double-flange beam, of uniform strength, of uniform depth, breadth parabolic; uniformly loaded.

Case 1. When the strength of both the flanges and the web is calculated :—

$$D = \frac{Wl^3}{8d''^2E(4a + 1\cdot167a'')} \quad . \quad . \quad . \quad . \quad (32)$$

Case 2. When the strength of the flanges only is calculated :—

$$D = \frac{Wl^3}{32ad''^2E} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (33)$$

11. Double-flange beam, of uniform strength, of uniform breadth, depth parabolic; uniformly loaded (fig. 70).

Case 1. When the strength of both the flanges and the web is calculated :—

$$D = \frac{Wl^3}{5\cdot33d''^2E(4a + 1\cdot167a'')} \quad . \quad . \quad . \quad . \quad (34)$$

Case 2. When the strength of the flanges only is calculated :—

$$D = \frac{Wl^3}{21\cdot33ad''^2E} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (35)$$

12. Double-flange beam, of uniform section, uniformly loaded.

Case 1. When the strength of both the flanges and the web is calculated :—

$$D = \frac{Wl^3}{6\cdot4d''^2E(4a + 1\cdot167a'')} \quad . \quad . \quad . \quad . \quad (36)$$

Case 2. When the strength of the flanges only is calculated :—

$$D = \frac{Wl^3}{25{\cdot}6d''^2E} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (37)$$

Note.—The last-named beam—of uniform section, uniformly loaded—is the most frequently occurring in practice, in the character of rolled wrought-iron joists.

Transverse Strength of Uniform Hollow Cylindrical Beams.

The transverse strength of a hollow cylinder is, of course, less than that of a solid cylinder of the same external diameter. The following coefficients may be substituted in formula (16) here repeated, with its converse, to find approximately the ultimate transverse strength of hollow cylinders, having bores of from ⅛th to ⅞ths of the external diameter of the cylinder :—

Solid cylindrical beam.

$$W = \frac{{\cdot}726d^3s}{l} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (38)$$

$$s = \frac{Wl}{{\cdot}726d^3} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (39)$$

Coefficients to be substituted in the formula for bores of various proportions.

	In parts of that of solid beam.	
	Coefficient.	Per cent.
Solid cylindrical beam	·726	100
Hollow cylindrical beam, bore ⅛th of external diameter	·689	95
” ” ” ” ¼ ”	·614	84·6
” ” ” ” ⅜ ”	·535	73·7
” ” ” ” ½ ”	·452	62·2
” ” ” ” ⅝ ”	·365	50·3
” ” ” ” ¾ ”	·269	37·0
” ” ” ” ⅞ ”	·160	22·0

Torsional Strength of Bars and Shafts.

The resistance of shafting to twisting or torsional stress is dependent upon its resistance to shearing stress. The ultimate torsional resistance of a uniform cylindrical bar or shaft is expressed by the following formulæ :—

Torsional Strength of a solid cylindrical shaft.

$$WR = {\cdot}196d^3s \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (40$$

$$W = \frac{{\cdot}196d^3s}{R} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (41$$

The ultimate torsional resistance of a hollow cylindrica shaft is expressed by the formulæ :—

Torsional Strength of a hollow cylindrical shaft.

$$WR = \frac{{\cdot}196(d^4 - d'^4)s}{d} \quad . \quad . \quad . \quad . \quad . \quad . \qquad (42$$

$$W = \frac{{\cdot}196(d^4 - d'^4)s}{Rd} \quad . \quad . \quad . \quad . \quad . \quad . \qquad (43$$

W = force applied at the end of the radius R, in tons.

R = length of radius at the end of which the force W i applied, at right angles, in inches.

d = diameter of the bar or shaft, in inches.

d' = diameter of the interior of a hollow shaft in inches.

b = breadth of side of square shaft.

s = ultimate shearing resistance, in tons per square inch o section.

When the section of a hollow bar, as a tube, is thin, comparatively to the diameter, the following formula may b employed :—

Torsional Strength of a thin tube.

$$WR = 1{\cdot}571d^2ts \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (44$$

$$W = \frac{1{\cdot}571d^2ts}{R} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (45$$

Torsional Strength of a solid square bar or shaft.

$$WR = {\cdot}281b^3s \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (46$$

$$W = \frac{{\cdot}281b^3s}{R} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (47$$

TABLE 173.—ULTIMATE STRENGTH OF COLUMNS OF VARIOUS CONSTRUCTION, WITH FLAT ENDS.

Description of Column.	Formula.	Authority.
1. Round cast-iron, solid or hollow	$W = \dfrac{36a}{1+\dfrac{r^2}{400}}$	Gordon.
2. Rectangular cast-iron, solid or hollow . .	$W = \dfrac{36a}{1+\dfrac{r^2}{500}}$	Gordon.
3. Rectangular wrought-iron, solid . . .	$W = \dfrac{16a}{1+\dfrac{r^2}{3000}}$	Stoney.
4. Angle, tee, channel, or cruciform iron . . .	$W = \dfrac{19a}{1+\dfrac{r^2}{900}}$	Unwin.
5. Solid round, mild steel .	$W = \dfrac{3a}{1+\dfrac{r^2}{1400}}$	Baker.
6. Solid round, strong steel .	$W = \dfrac{51a}{1+\dfrac{r^2}{900}}$	Baker.
7. Solid rectangular, mild steel	$W = \dfrac{30a}{1+\dfrac{r^2}{2480}}$	Baker.
8. Solid rectangular, strong steel	$W = \dfrac{51a}{1+\dfrac{r^2}{1600}}$	Baker.

W = breaking weight, in tons.
a = sectional area of the material, in square inches.
r = ratio of length to diameter. The diameter for calculation is the shortest diameter of the section.

Transverse Strength of Railway Rails.

The ordinary double-head rail, having heads of equal form and size, may be separated into the web for the whole depth, and the flange or overhung portion. The sectional area of the flange portions can be ascertained by dividing them into narrow horizontal strips, calculating the area of each strip separately, and taking the sums.

Transverse strength of a double-head rail.

$$W = \frac{s\left(4a'\frac{d''^2}{d} + 1{\cdot}167t'd^2\right)}{l} \quad . \quad . \quad . \quad . \quad . \quad (48)$$

W = breaking weight at the middle, in tons.
a' = net sectional area of one flange, in inches (excluding the central portion pertaining to the web).
d = total depth of the rail, in inches.
d'' = vertical distance apart of the centres of the flanges.
t' = thickness of the web.
l = length of span, between supports, in inches.
s = ultimate tensile strength, in tons per square inch.

Strength of Steel Springs.

The elasticity or deflection of laminated springs, with the working strength, are given by the following formulæ :—

$$E = \frac{1{\cdot}66l^3}{bt^3n} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (49)$$

$$s = \frac{bt^2n}{11{\cdot}3l} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (50)$$

$$n = \frac{1{\cdot}66l^3}{Ebt^3} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (51)$$

E = elasticity, or deflection, in sixteenths of an inch per ton of load.
s = working strength, or load, in tons.
l = span, when loaded, in inches.
b = breadth of plates, in inches, taken as uniform.
t = thickness of plates, in sixteenths of an inch.
n = number of plates.

Note.—The span and the elasticity are those due to the spring when weighted.

2. When extra thick back and short plates are used, they must be replaced by an equivalent number of plates of the ruling thickness, prior to the employment of the formulæ 49 and 50. This is found by multiplying the number of extra thick plates by the cube of their thickness, and dividing by the cube of the ruling thickness. Conversely, the number of plates of the ruling thickness given by formula 51, required

to be deducted and replaced by a given number of extra thick plates, are found by the same calculation.

3. It is assumed that the plates are similarly and regularly formed, and that they are of uniform breadth, and but slightly taper at the ends.

Helical Steel Springs.

$$E = \frac{d^3 w}{C D^4} \qquad \ldots \ldots \qquad (52)$$

E = compression or extension of one coil, in inches.
d = diameter from centre to centre of steel bar constituting the spring, in inches.
w = weight applied, in pounds.
D = diameter, or side of the square, of the steel bar, in sixteenths of an inch.
C = a constant, which may be taken as 22 for round steel, and 30 for square steel.

Note.—The deflection E for one coil is to be multiplied by the number of free coils, to obtain the total deflection for a given spring.

The relation between the safe load, size of steel, and diameter of coil, may be taken for practical purposes as follows:—

$$D = \sqrt[3]{\frac{wd}{3}}, \text{ for round steel} \quad . \quad . \quad (52a)$$

$$D = \sqrt[3]{\frac{wd}{4{\cdot}29}}, \text{ for square steel} \quad . \quad . \quad (52b)$$

STRENGTH OF TIMBER.

From the results of Mr. Laslett's experiments, the Table 174, of the direct ultimate tensile and compressive strengths of timbers has been compiled. For tensile strengths, the specimens were 2 inches square, and usually had a clear length of 30 inches. For compressive or crushing strength, the specimens were cubes of from 1 inch to 4 inches; and pieces 2 inches square and upwards, of various lengths. The crushing resistance of 1-inch, 2-inch, 3-inch, and 4-inch cubes of various woods, was practically the same per square inch of the upper surface, though there was a slight difference in favour of the smaller cubes.

TABLE 174.—TENSILE AND COMPRESSIVE STRENGTH OF TIMBER.

Woods.	Specific Gravity.	Tensile Resistance per Square Inch.	Crushing Resistance per Square Inch.
	Water = 1.	Tons.	Tons.
Oak, English	·858, 893	1·713, 3·380	3·337
,, French	·976	3·617	3·547
,, Dantzig	·838	1·882	3·344
,, American White	·969	3·143	2·709
,, African (or Teak)	·971	3·148	...
Teak, Moulmein	·777	1·474	2·559
Iron Wood, Burmah	1·176	4·311	5·208
Greenheart	1·141	3·937	6·438
Sabicu	·917	2·481	3·776
Mahogany, Spanish	·765	1·692	2·863
,, Honduras	·659	1·338	2·853
Eucalyptus, Tewart	1·169	4·591	4·174
,, Mahogany	·996	1·312	3·198
,, Iron Bark	1·150	3·740	4·601
,, Blue Gum	1·049	2·700	3·078
Ash, English	·750	1·687	3·109
,, Canadian	·588	2·453	2·453
Beech	·705	2·166	...
Elm, English	·642	2·437	2·583
,, Rock, Canada	·748	4·100	3·832
Hornbeam	·819	2·860	3·711
Fir, Dantzig	·603	1·442	3·102
,, Riga	·553	1·808	2·342
,, Spruce	·484	1·756	2·166
Larch, Russia	·649	1·876	2·596
Cedar	·469	1·281	2·000
Red Pine	·553	1·207	2·537
Yellow Pine	·551	1·120	1·877
Pitch Pine	·659	2·083	2·885
Kauri Pine	·544	1·803	2·867

The elastic tensile strength of timber is equal to, or nearly equal to, the ultimate tensile strength. Of Baltic timber, the elastic compressive strength is from 80 per cent. to 90 per cent. of the ultimate compressive resistance.

Columns of Timber.

observations of the crushing resistance of columns of wood, Mr. Laslett deduced that the maximum resistance of square pieces to compression is exerted when the sectional area in square inches is to the length in inches proportionally as 4 is to 5. for equal seasoning and equal specific gravities. In this ratio, the maximum resistance to crushing of 12-inch square balks on end, would be exerted for a length of 15 feet.

Timber Piles.

TABLE 175.—ULTIMATE STRENGTH OF TIMBER COLUMNS.
(Brereton and Stoney.)

Ratio of Length to Least Breadth.	Ultimate Weight that can be borne per Square Foot of Section.	Ratio of Length to Least Breadth.	Ultimate Weight that can be borne per Square Foot of Section.
	Tons.		Tons.
10	120	35	84
15	118	40	80
20	115	45	77
25	100	50	75
30	90		

Transverse Strength of Timber Beams, of Large Scantling, supported at the Ends, Loaded at the Middle.*

Fir . . . . . $W = \frac{1{\cdot}78bd^2}{l}$ . . (53)

Red pine . . . . $W = \frac{1{\cdot}39bd^2}{l}$ . . (54)

Quebec yellow pine . $W = \frac{1{\cdot}39bd^2}{l}$ . . (55)

Pitch pine . . . $W = \frac{2{\cdot}12bd^2}{l}$ . . (56)

English oak . . . $W = \frac{1{\cdot}64bd^2}{l}$ . . (57)

French oak . . . $W = \frac{2{\cdot}24bd^2}{l}$ . . (58)

W = breaking weight in tons.
b = breadth in inches.
d = depth in inches.
l = span in inches.

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* *Manual of Rules, Tables and Data*, page 550.

Deflection of Timber Beams of large Scantling, supported at the Ends, loaded at the Middle.

Fir . . . . $D=\frac{Wl^3}{bd^3}$ . . (59)

Red pine . . . $D=\frac{Wl^3}{2434bd^3}$ . . (60)

Quebec yellow pine . $D=\frac{Wl^3}{2084bd^3}$ . . (61)

Pitch pine . . . $D=\frac{Wl^3}{2968bd^3}$ . . (62)

English oak . . $D=\frac{Wl^3}{1848bd^3}$ . . (63)

French oak . . . $D=\frac{Wl^2}{2656bd^3}$ . . (64)

STRENGTH OF CAST-IRON.

The strength of cast-iron varies according to the distribution and massiveness of the metal. Thicker pieces are less strong than thinner pieces : an inequality which arises from the fact that the outer portions, at and near the surface of a casting, are denser, harder, and stronger than the central portions.

The tensile strength of cast-iron may be taken generally as equal to from 6 tons to 7 tons per square inch of section. Dr. Anderson deduced an average of 6 tons from a long series of tests. Mr. Hodgkinson, comparing the tensile strengths of bars of cast-iron 1 inch, 2 inches, and 3 inches square, found that they were relatively, per square inch, as 100, 66, and 60.

The ultimate compressive strength of cast-iron was determined by Mr. Hodgkinson to average 38½ tons per square inch.

The tensile strength of cast-iron is increased by re-melting. Sir Frederick Bramwell proved that the tensile strength of Acadian iron was increased from 7½ tons to 18½ tons by 8 hours of continued fusion and re-melting. The compressive strength averaged 3½ times the tensile strength. Sir Wm. Fairbairn increased the compressive strength of Eglinton hot-blast iron from 44 tons to 88 tons per square inch.

Cast-iron under tension or compression does not exhibit any well-defined elastic limit. Mr. Hodgkinson tested 1-inch square bars of cast-iron, 10 feet long, under a load of 5 tons in tension, the bar extended $\frac{1}{974}$th part of its length; under the same load in compression, the bar extended $\frac{1}{1109}$th part of its length. In round numbers, it may be taken that elastic extension and elastic compression are each approximately $\frac{1}{1000}$th part of the length, under a stress of 5 tons per square inch, or $\frac{1}{5000}$th part of the length per ton per square inch, which is more than twice the rate of elastic extension of iron or of steel.

Influence of high temperature.

Cast-iron of average quality loses strength when heated above 120° F.; and it becomes insecure at the freezing-point. At a red heat, its normal strength is reduced one-third.

Malleable cast-iron.

Cast-iron is rendered malleable by the extraction of part of the constituent carbon, approximating it to wrought-iron. The tensile strength of annealed malleable cast-iron is equivalent to over 25 tons per square inch; and 10 tons load per square inch is borne without distortion.

Columns.

TABLE 176.—SAFE LOAD ON HOLLOW CAST-IRON COLUMNS, WITH FLAT ENDS AND BASE PLATES: LENGTH = 20 TO 30 DIAMETERS.

(Shields.)

Thickness.	Load per Square Inch of Sectional Area of Metal.	
	Length 20 to 24 Diameters.	25 to 30 Diameters.
Inch.	Tons.	Tons.
$\frac{3}{4}$ and upwards	2	$1\frac{3}{4}$
$\frac{5}{8}$	$1\frac{3}{4}$	$1\frac{1}{2}$
$\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{4}$
$\frac{3}{8}$	$1\frac{1}{4}$	1

TABLE 177.—WEIGHT AND SAFE LOAD OF CAST-IRON COLUMNS, NOT EXCEEDING 20 DIAMETERS IN LENGTH.

(Load, two tons per square inch of sectional area.)

Thickness of Metal.	Mean External Diameter of Column, in Inches.														
	3			3½			4			4½			5		
	Area.	Weight per Lineal Foot.	Safe Load.	Area.	Weight per Lineal Foot.	Safe Load.	Area.	Weight per Lineal Foot.	Safe Load.	Area.	Weight per Lineal Foot.	Safe Load.	Area.	Weight per Lineal Foot.	Safe Load.
Ins.	Sq. Ins.	Lbs.	Tons.	Sq. Ins.	Lbs.	Tons.	Sq. Ins.	Lbs.	Tons.	Sq. Ins.	Lbs.	Tons.	Sq. Ins.	Lbs.	Tons.
Solid	7·07	22·2	14·1	...	...	...	...	...	...	...	...	...	...	...	...
1	6·28	19·8	12·6	7·85	24·7	15·7	9·42	29·7	18·8	10·99	34·6	22·0	12·57	39·6	25·1
1¼	...	...	...	8·84	27·8	17·7	10·80	34·0	21·6	12·76	40·2	25·5	14·73	46·4	29·5
1½	...	...	...	...	...	...	...	...	...	14·14	44·5	28·3	16·49	51·9	33·0

Thickness of Metal.	5½			6			7			8			9		
1	14·14	44·5	28·3	15·71	49·5	31·4	18·85	59·4	36·7	21·99	69·3	44·0	25·13	79·2	50·3
1¼	16·69	52·6	33·4	18·65	58·7	37·3	22·58	71·1	45·1	26·51	83·5	53·0	30·43	95·8	60·9
1½	18·85	59·4	37·7	21·21	66·8	42·4	25·92	81·6	51·8	30·63	96·5	61·3	35·34	111·3	70·7
1¾	21·35	67·2	42·7	23·36	73·6	46·7	28·86	90·9	57·7	34·36	108·2	68·7	39·86	123·6	79·7
2	...	...	...	25·13	79·2	50·3	31·42	99·0	62·8	37·70	118·7	75·4	43·98	138·5	88·0
2¼	...	...	...	...	...	...	33·57	105·7	67·1	40·64	128·0	81·3	47·71	150·3	95·4
2½	...	...	...	...	...	...	...	...	..	43·20	136·1	86·4	51·05	160·8	102·1

TABLE 177.—CAST-IRON COLUMNS (*continued*).

Thickness of Metal.	Mean External Diameter of Column, in Inches.														
	5½			6			7			8			9		
	Area.	Weight per Lineal Foot.	Safe Load.	Area.	Weight per Lineal Foot.	Safe Load.	Area.	Weight per Lineal Foot.	Safe Load.	Area.	Weight per Lineal Foot.	Safe Load.	Area.	Weight per Lineal Foot.	Safe Load.
Ins.	Sq. Ins.	Lbs.	Tons.	Sq. Ins.	Lbs.	Tons.	Sq. Ins.	Lbs.	Tons.	Sq. Ins.	Lbs.	Tons.	Sq. Ins.	Lbs.	Tons.
2¾	...	...	...	...	...	...	...	...	...	...	...	...	54·00	170·1	108·0
3	...	...	...	...	...	...	...	...	...	...	...	...	56·55	178·1	113·1
	10			11			12			13			14		
1	28·27	89·0	56·5	31·12	99·0	62·8	34·56	108·9	69·1	37·70	118·7	75·4	40·84	128·6	80·7
1¼	34·36	108·2	68·7	38·29	120·6	76·6	42·21	133·0	84·4	46·14	145·3	92·3	50·07	157·7	100·1
1½	40·06	126·2	80·1	44·77	141·0	89·5	49·48	155·9	99·0	54·19	170·7	108·4	58·90	185·5	116·8
1¾	45·36	142·9	90·7	50·85	160·2	101·7	56·35	177·5	112·7	61·85	194·8	123·7	67·35	211·1	134·7
2	50·27	158·3	100·5	56·55	178·1	113·1	62·83	197·9	125·7	69·11	217·7	138·2	75·40	237·5	150·8
2¼	54·78	172·5	109·6	61·85	194·8	123·7	68·92	217·1	137·8	75·99	239·4	152·0	83·06	261·6	166·1
2½	58·90	185·5	117·8	66·76	210·3	133·5	74·51	234·7	149·0	82·47	259·8	164·9	89·32	281·3	178·6
2¾	62·64	197·3	125·3	71·27	224·5	142·5	79·91	251·7	159·8	88·55	278·9	177·1	97·19	306·1	194·4
3	65·97	207·8	131·9	75·40	237·5	150·8	84·72	266·9	169·4	94·25	296·9	188·5	103·67	326·5	206·3
	15			16			17			18			19		
1	43·98	138·5	88·0	47·12	138·5	94·2	50·16	158·0	100·3	53·40	168·2	106·8	56·54	178·1	113·1
1¼	54·00	170·1	108·0	57·92	182·4	115·8	61·85	194·8	123·7	65·78	207·2	131·6	69·70	219·5	139·4

TABLE 177.—CAST-IRON COLUMNS (*continued*).

Thickness of Metal.	MEAN EXTERNAL DIAMETER OF COLUMN, IN INCHES.														
	15			16			17			18			19		
	Area.	Weight per Lineal Foot.	Safe Load.	Area.	Weight per Lineal Foot.	Safe Load.	Area.	Weight per Lineal Foot.	Safe Load.	Area.	Weight per Lineal Foot.	Safe Load.	Area.	Weight per Lineal Foot.	Safe Load.
Ins.	Sq. Ins.	Lbs.	Tons.	Sq. Ins.	Lbs.	Tons.	Sq. Ins.	Lbs.	Tons.	Sq. Ins.	Lbs.	Tons.	Sq. Ins.	Lbs.	Tons.
1½	63·62	200·4	127·2	68·33	215·2	136·7	73·04	230·1	146·1	77·75	245·9	155·5	82·47	259·8	164·9
1¾	73·03	230·0	146·1	78·34	246·7	156·7	83·84	264·1	167·7	89·34	281·4	178·7	94·83	298·7	189·7
2	81·68	257·3	162·4	87·96	277·1	175·9	94·25	296·9	188·5	100·53	316·7	201·1	106·81	336·4	213·6
2¼	90·12	283·9	180·2	97·19	306·1	194·4	104·26	328·4	208·5	111·33	350·7	222·7	118·40	373·0	236·8
2½	98·17	308·2	196·3	106·03	334·0	212·1	113·88	358·7	227·8	121·74	383·48	243·5	129·60	408·4	259·2
2¾	105·83	323·4	211·7	114·47	360·6	228·9	123·11	387·8	246·2	131·75	415·01	263·5	140·40	442·3	280·8
3	113·10	356·3	226·2	122·52	385·9	245·0	131·95	415·6	263·9	141·37	445·3	282·7	150·80	475·0	301·6
	20			21			22			23			24		
1	59·69	188·0	119·3	62·83	197·9	125·7	65·97	207·8	131·9	69·11	217·7	138·2	72·26	227·6	144·5
1¼	73·63	231·9	147·3	77·56	244·3	155·1	81·48	256·6	162·9	85·41	269·0	170·8	89·34	281·4	178·7
1½	87·18	274·6	174·4	91·89	289·4	183·8	96·61	304·3	193·2	101·31	319·1	202·6	106·03	334·0	212·1
1¾	100·33	311·5	200·7	105·83	323·4	211·7	111·33	350·7	222·7	116·83	368·0	233·7	122·32	385·3	244·6
2	113·1	356·2	226·2	119·38	376·0	238·7	125·66	395·8	251·3	131·94	415·6	263·9	138·23	435·4	276·5
2¼	125·47	395·2	251·9	132·54	417·5	265·1	139·60	439·7	279·2	146·67	462·0	293·3	153·74	494·3	307·5
2½	137·44	432·9	274·9	145·30	457·7	290·6	153·15	482·4	306·3	161·01	507·2	322·0	168·86	531·9	337·7
2¾	149·03	469·4	298·1	157·67	496·7	315·3	166·30	523·8	332·6	174·95	551·1	349·9	183·59	578·3	367·1
3	160·22	504·7	320·4	169·65	534·4	339·3	179·07	564·1	358·1	188·50	593·8	377·0	197·92	623·4	395·8

Transverse Strength of Cast-Iron.

The strength of beams of cast-iron varies very much according to the scantling. The breaking weights of 1-inch square bars of cast-iron supported at the ends, loaded at the middle, as tested by Mr. Barlow, and subsequently by Mr. Robert Stephenson, was expressed by the formula (65)

$$W = \frac{bd^2}{l} \times 13{\cdot}6 \quad . \quad . \quad . \quad . \quad (65)$$

in which W is the breaking weight in tons, and *b*, *d*, and *l*, are the breadth, depth, and length of span in inches. With 12 for a co-efficient, the formula shows that the breaking weight of a 1-inch square bar, at 12 inches of span, is just one ton: and if the span be expressed in feet, the formula (66) becomes

$$W = \frac{bd^2}{l} \quad . \quad . \quad . \quad . \quad (66)$$

in which *b* and *d* are in inches, and *l* in feet.

For the reason given, no constant coefficient can be employed with accuracy. The subjoined formulæ (67) and (68) give results which may safely be taken; for a minimum factor of 7 tons tensile strength per square inch, with a wide margin in excess.

Ultimate strength of rectangular bars of ordinary cast-iron, freely supported, loaded at the middle.

$$W = \frac{8bd^2}{l} \quad . \quad . \quad . \quad . \quad (67)$$

Ultimate strength of round bars of cast-iron.

$$W = \frac{5d^3}{l} \quad . \quad . \quad . \quad . \quad (68)$$

W, load in tons; *b*, *d*, and *l* in inches.

Deflection of cast-iron rectangular bars of uniform section loaded at the middle.

$$D = \frac{Wl^3}{28000bd^3} \quad . \quad . \quad . \quad . \quad (69)$$

D the deflection, and *b*, *d*, and *l* the breadth, depth, and span; all in inches.

Torsional Strength of Cast-Iron.

Solid round shaft . . . $WR = 1{\cdot}372d^3$ . . . . (70)

Hollow round shaft . . . $WR = \frac{1{\cdot}372(d^4 - d'^4)}{d}$ . . . (71)

Square shaft . . . . $WR = 1{\cdot}967b^3$ . . . . (72)

W = force applied, in tons.
R = radius of force, in inches.
d and *d′* = external and internal diameters, in inches.
b = side of square, in inches.

These formulæ are based on a tensile strength of cast-iron equal to 7 tons per square inch.

STRENGTH OF WROUGHT-IRON.

Mr. D. Kirkaldy's early experiments.

From the original and extensive results of Mr. David Kirkaldy's test-trials of bars and plates for tensile strength, the following summary results are obtained. His specimen bars were formed with a head at each end, with a clear length of 7 inches. The elongation or extension of the bars is added.

TABLE 178.—ULTIMATE TENSILE STRENGTH OF ROUND BAR IRON. (Mr. Kirkaldy.)

Bars.	Tons per Square Inch.	Extension before Fracture.
Yorkshire rolled bars	27·39	25·2 per cent.
Staffordshire ,, ...	25·90	23·5 ,,
Lanarkshire ,, ...	26·55	19·4 ,,
Rivet Iron ,, ...	26·00	20·5 ,,
Average	26·46	22·2 per cent.
Hammered scrap, forged down . .	23·85	24·8 per cent.
Crank shaft, scrap iron, with fibre .	20·37	21·8 ,,
,, ,, across fibre .	18·55	12·5 ,,
Armour plate, across fibre . .	16·92	9·0 ,,

The contracted sectional area of specimens tested to fracture, varied considerably, from 29·5 per cent. of the original area for Swedish charcoal iron bars to 85·2 per cent. for common Scotch iron bars. Thus—

Iron.	Fractured Sectional Area.
Swedish charcoal	29·5 per cent.
Staffordshire charcoal . . .	38·4 ,,
Yorkshire, Lowmoor	46·3 ,,
Staffordshire, B. B. Scrap . .	47·6 ,,
,, S. C. Crown . .	53·4 ,,
Scotch, extra best best . . .	58·5 ,,
,, best best	68·9 ,,
,, common	71·6 ,,
,, common	85·2 ,,

The strength as the diameter was reduced by rolling down from 1¼ to ½ inch, and intermediate sizes, was increased 19 per cent., or from 22·38 tons to 26·65 tons per square inch; whilst the extension was reduced from 28·3 per cent. to 23·8 per cent.

The strength of 1¼ inch rolled bars, turned down to 1 inch in diameter, was increased 5 per cent.; and the extension was augmented from 17·2 per cent. to 19·3 per cent.

Four 1¼ inch round bars, reduced by forging to 1 inch and ¾ inch in diameter, showed an increase of 4 per cent. of strength; and the extension was reduced from 24·5 per cent. to 17·3 per cent.

Five different 1 inch bars, when reheated for repair, showed 3·8 per cent. less tensile strength; and the extension was increased from 10·1 per cent. to 32·6 per cent.

Two pieces of a ¾ inch bar of iron were tested:—one in the ordinary condition; the other after having been heated to a welding heat, and cooled slowly. The strength was not materially affected, and the extension was reduced from 22·3 per cent. to 17·7 per cent.

To test the influence of intense cold, three pieces of a ¾ inch bar were tested: one at 64° F., the others at 23° F. The colder bars broke with 2·4 per cent. less load; and with an extension of 23 per cent., against 24·9 per cent. at 64° F.

To test the effect of notching a bar, several 1 inch round bars of different makes were notched or grooved to a diameter of ·7 inch, and broken at the notch; then turned down in the body to the same diameter, and broken through the body. The average tensile strengths per square inch, and the corresponding contracted sectional areas, were as follows:—

	Tensile Strength per Square Inch.	Contracted Sectional Area.
Notched . .	32·91 tons	85 per cent.
Turned down . .	27·61 ,,	58·4 ,,
Rough bar . .	26·04 ,,	59·9 ,,

Showing a remarkable excess of resistance at the notch relatively to the sectional area, and a relatively large contracted area.

The influence of screwing bolts of 1¼ inch, 1 inch, and ⅝ inch in diameter, on the tensile strength, showed 25 per cent. average reduction of tensile strength per square inch. Chased screws were weaker than screws made with dies, whilst screws cut with blunt dies were less weakened than those cut with new and sharp dies.

The influence of ordinary welded joints in several irons, showed an average of 19·4 per cent. reduction of tensile strength, varying from 2·6 per cent. to 43·8 per cent.

The effect of the sudden application of tensile stress to 1 inch round bars of iron, without blow or jerk, as against the gradual application of stress, was to reduce the load necessary to cause fracture by 18·6 per cent., with an extension of 20·1 per cent. as against 24·6 per cent. with the gradual application of the stress.

Three pieces of iron cut out of a large crank shaft, were forged down and turned to 1 inch in diameter. Tested against two other pieces cut out, and simply turned to 1 inch in diameter, they showed 20 per cent. greater strength, but reduced extension.

The influence of the removal of the skin on strength of hammered iron, was shown by two 1½ inch square bars turned down to 1 inch in diameter, the tensile strength being 5¾ per cent. more than that of 1-inch square hammered bars in their skins, with a greater degree of extension.

A 1¼-inch round bar of Bowling iron was cut into several pieces, which were turned, forged down and hardened, with the following results:—

Diameter.		Tons per Sq. In.	Extension.
Turned to 1 inch	. . . .	27·15	28·3 per cent.
Forged to ·87 ,,	hardened in water	32·79	19·6 ,,
,, ,, ·78 ,,	,, oil	28·85	19·8 ,,
,, ,, ·70 ,,	,, tar	28·06	22·4 ,,

The second of these tensile strengths, 32·79 tons per square inch, was the maximum tensile strength of iron observed by Mr. Kirkaldy.

By casehardening and cooling in water, or in oil, or slowly, an average of 8·4 per cent. reduction of tensile strength was effected, with only one-fourth of the extension.

In cold-rolling ¾-inch bars, the tensile strength was mented 18 per cent., and the elongation reduced to on By subsequent annealing, the gain of strength disappea

Angle-iron, ship-strap, and beam-iron are less in tensile strength by from 1 ton to 2 tons per square inch than bar iron ; and the extensions also are less.

Mr. Kirkaldy found that the density of iron was diminished by cold-rolling :—

	Ordinary.	Cold Rolled.	Reduced.
Bar iron, specific gravity .	7·636	7·582	·7 per cent.
Boiler plate „ .	7·566	7·539	·37 „

The specific gravity of iron was also reduced by stretching under tensile stress :—

	Specific Gravity.	
	Before stretching.	After stretching.
Three 1-inch Yorkshire iron bars, stretched to ·90 inch diameter.	7·752	7·674
Two ·83-inch Blochairn bars, stretched to ·76-inch diameter .	7·636	7·569
Average for five bars .	7·760	7·632

Showing an average of ·128 reduction of specific gravity, or 1·65 per cent.

Swedish Hammered Bar Iron.

Mr. Kirkaldy tested round bars, 3 inches, 2 inches, 1 inch, and ½ inch in diameter, with flat bars ½ inch thick, by 3 inches, 2 inches, and 1½ inches wide, for tensile strength. The round specimens had 10 inches of clear length, and the flat specimens 15 inches.

The average ultimate strength of the round bars was 20·13 tons per square inch, with an extension of 24·6 per cent. ; and that of the flat bars was 21·4 tons, with an extension of 16·7 per cent. 1½ inch turned specimens had an elastic strength of 11·05 tons, about 60 per cent. of the ultimate strength, 18·80 tons.

Under compressive stress three 1½ inch round specimens, respectively 1½, 3, and 15 inches high, were crushed under a stress of 66·45, 37·90, and 12·53 tons per square inch.

A 1-inch cube failed under a load of 82·20 tons.

French Bar Iron.

The strength of French bar iron of various denominations is given in Table 179.

TABLE 179.—FRENCH BAR IRON—TENSILE STRENGTH.

(Debauve.)

Description.	Ultimate Strength in Tons per Square Inch.	Extension.
	Tons.	Per cent.
Creusot, No. 1, Rails	26·03	10
„ No. 2, Merchant Iron	24·00	15
„ No. 3, Horse-shoe Iron	24·13	18
„ No. 4, Bolts and Rivets	24·45	21
„ No. 5, Boiler Plates	24·51	25
„ No. 6, Machinery Iron	24·57	29
„ No. 7, Exceptional	24·89	34
Chantillon and Commentry, No.1, Axles	22·86	25
„ „ No.5	26·35	13
Terre-Noire, La Voulte, and Bessèges :		
Ordinary	18·42	17
Strong	20·96	20
Superior	21·59	25
Fine	23·50	26
Saint Étienne, granular, No. 1	17·78	...
„ „ No. 7	22·86	12
„ fibrous, No. 1	16·51	2
„ „ No. 7	22·86	18
Porte Évèque (Isère), No. 1	6·35 to 12·70	...
„ „ No. 7	21·59	18
Lyons Railway Company :		
No. 1, fine charcoal	24·13	25
No. 2, strong superior	23·50	23
No. 3, strong	22·23	18
No. 4, ordinary	20·96	12

In general, good ordinary French wrought-iron takes a tensile breaking weight of from 22 tons to 24 tons per square inch. The limit of elasticity corresponds to 6½ tons per square inch, whilst the maximum stress allowed in construction is 6 kilogrammes per square millimetre, or 3·81 tons per square inch, about ⅙th of the ultimate strength. In compression, the elastic limit is for fine-grain iron 3·81 tons, and for fibrous iron, 9 tons; with ultimate rupturing stresses of 63 tons and 51 tons respectively.

Mr. Kirkaldy's Experiments with Iron Plates.

The tensile strength of iron plates, from ⅜ inch to ¾ inch thick, in specimens 1½ inches and 2 inches wide, is given in Table 180 :—

TABLE 180.—ULTIMATE TENSILE STRENGTH OF IRON PLATES.

(D. Kirkaldy.)

Plates.	Tons per Square Inch.		Extension.	
	With Fibre.	Across Fibre.	With Fibre.	Across Fibre.
	Tons.	Tons.	Per cent.	Per cent.
Yorkshire . .	24·75	22·64	13·4	8
Staffordshire . .	23·01	21·40	9·3	5·3
Durham . .	22·89	21·39	9·5	5·2
Shropshire . .	23·37	19·22	9·6	2·8
Lanarkshire .	21·96	19·56	7·0	3·2
Averages . . .	23·20	20·84	9·8	4·9

The tensile strength across the fibre is from 1½ tons to 4 tons per square inch less than that with the fibre. The average difference is 10 per cent.

Fractured Sectional Area of Iron Plates.

	With Fibre.		Across Fibre.		
Yorkshire . .	63·5	per cent.	79·7	per cent. of	original area.
" . .	76·5	"	83·7	"	"
Staffordshire S. C. Crown	78·5	"	89·9	"	"
Staffordshire Bradley . .	84·3	"	92·0	"	"
Scotch best boiler . .	87·3	"	93·6	"	"
Staffordshire best best .	90·9	"	94·6	"	"
Scotch Ship .	95·4	"	97·5	"	"
Scotch common	94·4	"	98·5	"	"
Averages .	84·0		91·0		

By cold-rolling, pieces of Blochairn plate ·345 inch thick, rolled to two-thirds of their thickness, were nearly doubled in strength, but the extension was annihilated. By annealing after cold-rolling, only 2½ tons of the gain of strength remained, and the extension was doubled.

Krupp Iron Plates.

Mr. Kirkaldy tested a number of Krupp iron plates, and, for comparison, Lowmoor plates, ⅜ inch, ½ inch, and ⅝ inch thick, for which testing specimens 2 inches wide, 10 inches long for extension were prepared. The specimens were tested lengthwise, crosswise, annealed and unannealed. The total average results were as follows :—

	Krupp.	Yorkshire.
Elastic strength per square inch	11·2 tons	12·2 tons
Ultimate „ „ „	21·5 „	20·2 „
Ratio of elastic to ultimate strength	52·1 per cent.	60·4 per cent.
Extension at 30,000 pounds per square inch	1·94 „	·85 „
Ultimate extension . . .	22·6 „	14·8 „
Sectional area of fracture . .	66·2 „	81·4 „

The elastic strength of the annealed specimens was from ·30 to ·60 tons less than that of the unannealed specimens.

TABLE 181.—ULTIMATE TENSILE STRENGTH OF GALVANISED IRON SHEETS.

Thickness.	Extension in 10 Inches.	Resistance per Square Inch.
	Per cent.	Tons.
B. W. G. No. 25, with fibre . .	9	27·4
„ „ across fibre . .	7·4	21·8
„ No. 23, with fibre . .	8·5	26·2
„ „ across fibre . .	6·3	22·1
„ No. 21, with fibre . .	9·9	24·6
„ „ across fibre . .	11·2	21·0

French Plate Iron and Sheet Iron.

Iron plates and sheets are generally disposed in six classes. For example :—

	Tensile Strength per Square Inch.	Extension.
Creusot :—		
No. 2	21·08 tons	6 per cent.
„ 3	21·40 „	10 „
„ 4	22·08 „	14 „
„ 5	22·10 „	18 „
„ 6	22·61 „	22 „
„ 7	23·30 „	26 „
Denain and Anzin :—		
No. 2	19·05 tons	3 per cent.
„ 3. Boilers	19·05 „	5 „
„ 4. Common for the Marine	20·96 „	8 „
„ 5. Ordinary „ „	22·22 „	12 „
„ 6. Superior „ „	22·86 „	18 „
„ 7. Fine „ „	23·50 „	20 „

In general, the resistance of the plates for the marine across the grain is from 2½ tons to 3¾ tons less than with the grain.

Influence of Temperature on the Tensile Strength of Wrought-Iron.

According to the results of Sir Wm. Fairbairn's experiments, the strength of ordinary Staffordshire plates, either with or across the grain, remained the same for temperatures varying from 0° F. to 400° F. This higher temperature is that of steam of 235 lbs. effective pressure per square inch. At higher temperatures, the strength declined until, at a red heat, it fell from an average of 20 tons to 15¼ tons per square inch.

TABLE 182.—DECREASE IN TENSILE STRENGTH OF WROUGHT-IRON, WITH RISE OF TEMPERATURE.

(Kollman.)

Temperature.		Decrease in Strength.	Temperature.		Decrease in Strength.
Centigrade.	Fahrenheit.	Per cent.	Centigrade.	Fahrenheit.	Per cent.
°	°		°	°	
0	32	...	600	1112	81
200	392	5	700	1292	84
300	572	10	800	1472	89
400	752	27	1000	1832	96
500	932	62			

M. Debauve states that the statical resistance is not affected by cold; but that the resistance to shocks is diminished by it. For temperatures from 0° C. to 100° C., or 32° F. to 212° F., there is no change; at 200° C., or 392° F., the tensile resistance is reduced 5 per cent.; at 300° C., or 572° F., reduced 10 per cent.; at 500° C., or 932° F., 60 per cent.; at 700° C., or 1292° F., 80 per cent.; at 900° C., or 1,652° F., 90 per cent.; at 1,000° C., or 1,832° F., the reduction of strength amounts to 95 per cent., leaving 5 per cent. of resisting strength. These results have been obtained for fibrous iron, fine grain iron, and Bessemer steel.

Working Temperatures.

The leading temperatures at which iron is worked are these:—

Brown-Red Heat, about 700° C., or 1,300 F.: the lower limit for working iron.

Cherry-Red Heat, about 950° C., or 1,730° F.: iron can be dressed, or rectified.

Red-White Heat, about 1,300° C., or 2,370° F.; iron easily worked.

Welding Heat, about 1,500° C., or 2,730° F.

Experiments of the Steel Committee of Civil Engineers, with Bar Iron.

1½ inch round bars of Lowmoor iron, and S. C. Crown, Staffordshire iron, were tested for tensional strength and compressive strength, to the elastic limit, as well as for ultimate tensile strength. The bars were in lengths of 10 feet, for tension and for compression.

The summary average results of the tests are given in Table 183 (p. 355).

Transverse Strength of Wrought-Iron.

The general formula (3), page 322, as follows:—

$$W = \frac{1{\cdot}167 bd^2 s}{l} \quad . \quad . \quad . \quad . \quad (73)$$

gives the transverse strength of wrought-iron beams, supported at both ends and loaded at the middle, by substituting for s the ultimate tensile strength of the metal. Taking $s = 20$ tons per square inch.

Transverse Strength of Wrought-Iron Beams or Bars supported at both ends, loaded at the middle.

Square or Rectangular $W = \frac{23 \cdot 3bd^2}{l}$ . . . (74)

Round . . . . $W = \frac{14 \cdot 6d^3}{l}$ . . . . (75)

W = load at middle, in tons.
b = breadth of beam, in inches.
d = depth or diameter, in inches.
l = span, in inches.

For wrought-iron beams of other tensile strength, the co-efficients to be employed in equations (74) and (75), are as follows :—

Tensile Strength.	Coefficient for Equation (74).	For Equation (75).
21 tons	24·5	15·3
22 "	25·7	16·0
23 "	26·8	16·8
24 "	28·0	17·5
25 "	29·2	18·2

Elastic Transverse Strength of Wrought-Iron.

Rectangular section . . . $D = \frac{Wl^3}{47{,}000bd^3}$ . . . (76)

Round section . . . . $D = \frac{Wl^3}{32{,}000d^4}$ . . . (77)

D = deflection in inches.
W = load at middle, in tons.
b = breadth in inches.
d = depth, or diameter, in inches.
l = span in inches.

Torsional Strength of Wrought-Iron Bars or Shafts.

Taking the ultimate tensile strength of wrought-iron bars and shafts at 22½ tons per square inch, on an average, the formulæ for the torsional strength of wrought iron are (p. 356) :—

TABLE 183.—STRENGTH OF ROUND WROUGHT-IRON BARS, 1½ INCHES DIAMETER, 10 FEET LONG.

(The Steel Committee.)

I. TENSILE STRENGTH (Summary Averages).

Description of Iron.	Elastic Strength in Tons per Square Inch.	Elastic Extension in parts of the Length.		Breaking Weight in Tons per Square Inch.	Permanent Extension.	Ratio of Elastic to Breaking Strength.	Sectional Area of Fracture.
		Total.	Per Ton per Square Inch.				
	Tons.	Per cent.	Length = 1.	Tons.	Per cent.	Per cent.	Per cent.
Yorkshire	13·0	·103, or 1 in 974	·000079, or $\frac{1}{12658}$	25·8	12·5	50·6	64·6
S. C. Crown, Staffordshire	11·8	·096, or 1 in 1046	·000081, or $\frac{1}{12346}$	22·6	17·5	52·2	52·3
Mean . . .	12·4	·100, or 1 in 1000	·000080, or $\frac{1}{12500}$	24·2	15·0	51·4	58·4
II. COMPRESSIVE STRENGTH (Summary Averages).							
		Elastic Compression.					
Yorkshire	12·6	·097, or 1 in 1030	·000077, or $\frac{1}{12987}$	...	...	...	...
S. C. Crown, Staffordshire	11·7	·097, or 1 in 1030	·000083, or $\frac{1}{12048}$	...	...	...	...
Mean . . .	12·1	·097, or 1 in 1030	·000080, or $\frac{1}{12500}$	...	...	...	...

Ultimate Torsional Strength of Wrought-Iron Bars or Shafts.

Round bar or shaft $WR = 4{\cdot}41d^3$ . . . . . (78)
" " " $d = {\cdot}283\sqrt{WH}$ . . . (79)
Square " " $WR = 6{\cdot}32b^3$ . . . . (80)
" " " $b = {\cdot}251\sqrt[3]{WH}$ . . . (81)

The elastic torsional strength is about 40 per cent. of the ultimate torsional strength.

Torsional deflection of wrought-iron bars and shafts within the elastic limit, is given by the formula :—

Elastic Torsional Deflection of Wrought-Iron Bars and Shafts.

$$D = \frac{WRl}{1072d^4} \quad . \quad . \quad . \quad . \quad . \quad . \qquad (82)$$

W = force in tons
R = radius of force, in inches.
WR = moment of force, in statical inch-tons.
d = diameter of round shaft, in inches.
b = side of square shaft, in inches.
l = length of shaft subject to torsional action, in inches.
D = total angular deflection in parts of one revolution.

STRENGTH OF STEEL.

The qualities of iron and steel depend principally on the proportion of constituent carbon, thus :—

	Percentage of Carbon.
Ordinary iron Either soft or mild steel	0 to 0·15
Granular iron Soft or mild steel	0·15 to 0·45
Steely iron or puddled steel Semi-mild steel	0·45 to 0·55
Cemented steel Hard steel	0·55 to 1·50
Cast-iron	1·5 to 5

Mr. Kirkaldy's Experiments.

Steel bars of from ½ inch to 1 inch in diameter were tested, and proved to from an average of 59 tons per square inch for tool steel, to an average of 29 tons for puddled steel. The greatest observed ultimate strength was 66·2 tons per square inch for tool-steel. The general results are given in Table 184.

TABLE 184.—BAR STEEL: TENSILE STRENGTH.

(Mr. Kirkaldy—Summary.)

Name.	Treatment.	Size.	Breaking Weight per Sq. Inch (average).	Extension.
		Inch.	Tons.	Per cent.
Tool steel . .	Forged	·53 to ·59	59·21	5·3
Chisel steel . .	,,	·56 to ·60	55·75	7·1
Shear steel . .	,,	·56 and ·57	52·87	13·5
Drift steel . .	,,	·57	51·76	13·3
Bessemer tool steel	,,	·65 to ·75	49·75	5·5
Rivet steel . . .	Rolled	·75	47·75	10·5
Blister steel . .	Forged	·57 to ·60	46·56	9·7
Steel for taps . .	,,	·57 and ·59	45·15	10·8
Krupp's bolt steel.	Rolled	·91 to ·93	41·08	15·3
Homogeneous metal . .	,,	·56	40·47	13·7
,, ,,	Forged	·75	40·05	11·9
Spring steel . .	,,	·55 to ·57	32·37	18·0
Puddled steel . .	Rolled	·75 to 1	31·32	11·3
,, ,, .	Forged	·75 and ·77	29·40	13·4

Experiments of the Steel Committee with Bar Steel.*

In the second series of experiments made at Woolwich Dockyard the object was to make experiments on the tension of long steel bars and iron bars, measuring the changes of length directly from the bars. For this purpose 91 round bars of steel and iron, each 14 feet long, 1½ inches in diameter, were procured, consisting of 33 bars of crucible steel, 34 bars of Bessemer steel, 12 bars of Lowmoor iron, 6 bars of best Yorkshire iron, and 6 bars of usual S. C. Crown, or Staffordshire iron. The extensions were measured on 10 feet length of each bar, and for compressive tests, the bars were cut to a length of 12 feet, and the measurements made on a length of 10 feet. The bars were tested in their natural skins. They were thoroughly examined, straightened, and gauged before being

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* For a detailed notice of these important experiments, see *Manual of Rules, Tables, and Data*, pages 579, 596.

TABLE 185.—STRENGTH OF STEEL BARS $1\frac{1}{2}$ INCHES IN DIAMETER, 10 FEET LONG.

(The Steel Committee.)

I. TENSILE STRENGTH (SUMMARY AVERAGES.)

Description of Steel.	Elastic Strength in Tons per Square Inch.	Elastic Extension, in parts of the Length.		Breaking Weight in Tons per Square Inch.	Permanent Extension.	Ratio of Elastic to Breaking Stress.	Sectional Area of Fracture.
		Total.	Per ton per Square Inch.				
	Tons.	Per cent.	Length = 1.	Tons.	Per cent.	Per cent.	Per cent.
Crucible	23·4	·182, or 1 in 550	·000078, or $\frac{1}{12850}$	40·88	5·1	58·0	90·6
Bessemer	18·4	·144, or 1 in 695	·000078, or $\frac{1}{12780}$	34·22	12·0	53·8	62·5
Mean	20·9	·163, or 1 in 613	·000078, or $\frac{1}{12780}$	37·55	8·5	55·9	76·6
II. COMPRESSIVE STRENGTH (SUMMARY AVERAGES.)							
		Elastic Compression.					
Crucible	23·3	·175, or 1 in 570	·000076, or $\frac{1}{13250}$	...	...	...	...
Bessemer	17·8	·137, or 1 in 732	·000077, or $\frac{1}{13040}$	...	...	...	...
Mean	20·5	·156, or 1 in 641	·000076, or $\frac{1}{13140}$	...	...	...	...
	Bars tested for Compression, but not for Tension.						
Crucible: axles, rails, tyres	23·0	·172, or 1 in 581	·000073, or $\frac{1}{13700}$	...	...	...	...
Bessemer: axles, rails, tyres	24·0	·182, or 1 in 550	·000074, or $\frac{1}{13514}$	...	...	...	...

tested. The summary results have been given for bar iron, page 349, and those for the steel bars in Table 185, preceding.

The average compositions of the foregoing steels and the Yorkshire iron tested at the same time were as follows:—

	Crucible Steel. Per cent.	Bessemer Steel. Per cent.	Yorkshire Iron. Per cent.
Iron	98·89	99·20	99·49
Carbon . . .	·62	·33	·23
Silicon . . .	·114	·022	·10
Manganese . . .	·34	·39	·08
Sulphur . . .	·01	·035	·02
Phosphorus . . .	·026	·02	·08
	100·000	99·997	100·00
Specific gravity .	7·842	7·855	7·758

Hadfield's Manganese Steel.

Though steel becomes brittle when the constituent manganese exceeds 2·75 per cent., yet it has been proved by Mr. R. A. Hadfield that when there is a proportion of not less than 7 per cent. of manganese, up to about 20 per cent., the product is a new metal, of superior strength. The Table 186 gives comparative tensile strengths and extensions of Siemens and Bessemer steels, including manganese steel of the following composition:—iron, 98·00, carbon, ·85, silicon, ·23, sulphur, ·08 phosphorus, ·09, and manganese, 13·75 per cent.

TABLE 186.—MANGANESE STEEL AND OTHER MILD STEELS

Description.	Breaking Loads.	Extension.
	Tons.	Per cent.
Siemens	26·16 to 28·51	31·25 to 35·69
Siemens	26·26 „ 28·21	32·78 „ 37·50
Bessemer . . .	20·21 „ 28·44	31 „ 35
Siemens	25·10 „ 27·21	31 „ 34
Basic Bessemer . .	22·20 „ 25·80	30 „ 34
Siemens	26·54 „ 28·29	28 „ 31
Manganese steel . .	57 „ 65	39·8 „ 50·7

TABLE 187.—COMPRESSED STEEL: TENSILE STRENGTH.
(W. H. Greenwood.)

Description.	Elastic limit, per Sq. Inch.	Ultimate Strength per Sq. Inch.	Contraction of Area at Fracture.	Extension in Four Inches.
I. *Test pieces cut longitudinally:—*	Tons.	Tons.	Per cent.	Per cent.
Unpressed ingot.	11·11	29·18	4·41	8·76
Pressed ingot .	14·45	29·53	7·90	12·51
II. *Test pieces cut transversely:*				
Unpressed ingot.	11·43	28·04	3·61	7·91
Pressed ingot .	12·38	30·07	7·57	12·74

Whitworth Compressed Steel.

Steel subjected by the Whitworth process to compression while fluid, under a pressure of from 4 tons to 12 tons per square inch, gains in solidity and strength. In one instance the specific gravity of sound crucible steel containing 0·54 per cent. of carbon, was increased by compression from 7·8542 to 7·8795. The density of steel as a whole is increased by from 8 per cent. to 12 per cent. by compression pressure. Two sample ingots, pressed and unpressed, contained respectively 0·5 per cent. and 0·39 per cent. of carbon, and 0·35 per cent. and 0·4 per cent. of manganese. The results of tests for tensile strength are given in Table 187, the data of which are given by Mr. W. H. Greenwood. There is practically very little difference in the strengths of pieces cut longitudinally and transversely. But there is a considerable augmentation of elastic strength by compression.

Strength of Steel Plates.

Mr. Kirkaldy tested a number of steel plates for tensile strength, the results of which are summarised in Table 189. The plates were from $\frac{3}{16}$ inch to $\frac{4}{16}$ inch thick; and it is shown that whilst the puddled steels possessed about 10 per cent. less ultimate strength across the fibre than with it, the cast steel plates were at least as strong crosswise as lengthwise.

Landore steel plates tested by Mr. Kirkaldy were shown to have the same resisting strength lengthwise and crosswise as in the following Table 188. It is shown that the annealed samples have about 7½ per cent. less tensile resistance than unannealed samples.

TABLE 188.—LANDORE STEEL PLATES: TENSILE STRENGTH.

	Tensile Strength per Square Inch.			
	With the Grain.		Across the Grain.	
	Annealed.	Un-annealed.	Annealed.	Un-annealed.
Elastic strength, tons	12·8	14·5	12·8	14·4
Ultimate strength "	28·8	31·1	28·8	31·2
Contraction of area at fracture, p. cent.	43·2	41·1	44·9	40·5
Extension "	24·6	23·4	23·6	23·5

TABLE 189.—STEEL PLATES: TENSILE STRENGTH.
(Mr. Kirkaldy—Summary.)

Description of Steel.	Thickness of Plate.	Breaking Weight per Square Inch.		Extension in parts of the Length.	
		With Fibre.	Across Fibre.	With Fibre.	Across Fibre.
	Inch.	Tons.	Tons.	Per cent.	Per cent.
Cast steel . .	$\frac{3}{16}$ to $\frac{3}{8}$	38·82	39·90	12·90	13·96
Puddled steel .	$\frac{1}{8}$ to $\frac{5}{16}$	41·56	35·34	5·12	2·82
Mild puddled steel . .	$\frac{1}{4}$ to $\frac{9}{32}$	33·16	30·22	4·90	5·70
Hard puddled steel . .	$\frac{1}{4}$	45·80	38·11	4·90	3·30
Total averages	$\frac{3}{16}$ to $\frac{3}{8}$	39·83	35·90	6·95	6·44

The following results of tests of hematite steel and Krupp steel are given as examples comprising ultimate compressive strength :—

	Hematite.	Krupp.
Elastic tensile strength, per square inch	18·63 tons	19·10 tons
Ultimate tensile strength, per square inch	32·27 "	42·07 "
Extension	19·2 per cent.	7·9 per cent.
Elastic compressive strength .	23·21 tons	21·13 tons
Ultimate " " .	71·24 "	89·30 "

Strength of Steel as affected by its Chemical Composition.

TABLE 190.—BESSEMER STEEL (FOR TYRES): CHEMICAL COMPOSITION AND TENSILE STRENGTH.
(J. O. Arnold—Summary.)

Chemical Composition.							Tensile Strength.			
Iron.	Carbon.	Chromium.	Manganese.	Silicon.	Sulphur.	Phosphorus.	Ultimate, in Tons per Sq. Inch.	Extension.	Reduction of Area.	Fracture.
Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Tons.	Per cent.	Per cent.	
98·24	·28	...	1·25	·07	·08	·08	37	26	47	Gray granular. Convex and concave.
97·74	·25	...	1·75	·03	·12	·11	42·1	18	26·3	Gray granular, flat.
97·49	·28	·42	1·54	·08	·10	·09	49·8	15	26	Finely crystalline, flat.
97·69	·32	·30	1·46	·11	·05	·07	50	16	29	Coarse granular.
97·42	·28	·64	1·41	·11	·07	·07	50·4	10	13·8	Crystalline.
SPRING STEEL.										
										Description.
98·24	·50	...	1·10	·07	·09	·08	50·8	14·9	31·4	Unhardened.
							69·4	10·9	30·0	Water hardened.
							88·0	3·1	4·9	Oil hardened.

The Table 190, gives the experimental results of tests of Bessemer tyre-steel, conducted by Mr. J. O. Arnold, with the chemical composition of the steels tested. These comprise samples containing various proportions of chromium and manganese, as well as of carbon. An example of spring steel is introduced in this Table, showing the hardening influence of water and of oil.

Another Table 191, of the transverse strength of steel rails, shows also the variations of transverse strength with the percentage of carbon. The rails were double-headed, 5½ inches deep, weighing 86 pounds per yard; and whilst the carbon ~~increased from ·40 per cent. to ·55 per cent., the ultimate loads~~ were increased from 40 tons to 52½ tons.

TABLE 191.—TRANSVERSE STRENGTH OF STEEL RAILS IN RELATION TO THE CONSTITUENT CARBON.

Span 43·5 inches. Load applied at the middle.

Constituent Carbon.	Ultimate Strength.			Elastic Strength.			
	Load.	Deflection.	Set.	Load.		Deflection.	Set.
Per cent.	Tons.	Inch.	Inch.	Tons.	Per cent.	Inch.	Inch.
·40	40	3·94	3·74	15	37·5	·10	·01
·46	40	2·64	2·34	20	50	·14	·05
·49	50	4·18	3·77	22·5	45	·165	·03
·50	52·5	4·68	4·28	22·5	43	·130	·01
·55	52·5	4·40	4·02	25	48	·165	·04

TABLE 192.—TENSILE STRENGTH OF STEEL RAILS IN RELATION TO THE CONSTITUENT CARBON.

Constituent Carbon.	Ultimate Tensile Strength, in Tons per Square Inch.	Constituent Carbon.	Ultimate Tensile Strength, in Tons per Square Inch.
Soft Rails.		Hard Rails.	
Per cent.	Tons.	Per cent.	Tons.
·28	30·90	·36	37·01
·29	32·60	·39	41·41
·30	32·94	·40	37·68
·31	32·67	·43	39·10
·32	33·04	·44	41·02
		·45	44·00
		·50	45·79
		·57	50·42

Thirty Bessemer steel rails, manufactured at Barrow-in-Furness, comprising various proportions of constituent carbon, were tested for tensile strength, with the results given by Mr. J. T. Smith in Table 192, showing that the tensile strength increased from 30·9 tons to 50·42 tons per square inch, with the proportions of carbon from ·28 to ·57 per cent.

TABLE 193.—TENSILE STRENGTH OF STEEL IN RELATION TO THE CONSTITUENT CARBON.

Description of Steel.	Constituent Carbon (Approximate).	Breaking Weight per Square Inch.	Extension.
	Per cent.	Tons.	Per cent.
Webb steel . . .	·20	28·0	...
Vickers No. 2 . .	·33	30·4	9·8
,, No. 4 . .	·43	34·0	9·8
,, No. 5 . .	·48	37·5	8·9
,, No. 6 . .	·53	42·5	8·0
,, No. 8 . .	·63	45·0	7·1
,, No. 10 . .	·74	45·5	5·0
,, No. 12 . .	·84	55·0	8·0
,, No. 15 . .	1·00	60·0	5·0
,, No. 20 . .	1·25	69·0	4·4

The influence of the constituent carbon on the tensile strength of steel was well exemplified by Mr. T. Edward Vickers in 1861, as shown in the Table 193. To render the table fuller, the strength and constituent carbon of Mr. Webb's steel for boiler plates are prefixed, in the first line. The specimens of Mr. Vickers were made of crucible steel from Swedish iron. They were turned to a diameter of 1 inch for a clear length of 14 inches. It is shown that the ultimate tensile strength increases with the carbon from 28 tons, with ⅕th per cent. of carbon, to 69 tons per square inch with 1¼ per cent. of carbon.

M. Debauve gives the following evidence of the influence of the constituent carbon, in the case of steel bars tempered in oil :—

Constituent carbon ·15, ·49, ·709, ·875 per cent.

Elastic limit . 20·32, 27·94, 43·18, 57·15 tons per square inch.

Ultimate strength	29·21, 46·45, 67·94, 67·31 tons per square inch.
Extension in inches . .	28, 12, 4, 1 per cent.

Strength of Long Round Steel Columns.

The safe working load for long round steel columns is given by means of the following formula :—

$$W = 1400 \frac{d^3}{l^2} \quad . \quad . \quad . \quad . \quad . \quad . \quad (83)$$

W = safe load in cwts.
d = diameter of column in inches.
l = length of column between supports or brackets, in feet.

This formula is specially applicable to the case of hydraulic lifts, as well as to the case of fixed loads. It may be properly employed for columns of from 3 inches to 5 inches in diameter, and for lengths of from 25 feet up to 50 feet, for columns not less than 3 inches in diameter; and up to 80 feet for 5-inch columns. Table 194 has been calculated by means of the above formula.

TABLE 194.—SAFE LOAD ON LONG ROUND STEEL COLUMNS.

Diameter of Column.	Length of Column between Supports, in Feet.								
	25	30	35	40	45	50	60	70	80
Inches.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.
3	60·5	42·0	30·8	23·6	18·6	15·1	...	...	...
3¼	76·8	53·4	39·2	30·0	23·7	19·2	...	...	...
3½	96·0	66·7	49·0	37·5	29·6	24·0	16·7	...	...
4	143·0	99·6	73·1	56·0	44·2	35·8	25·0	...	...
4½	204·1	141·7	104·1	79·7	63·0	51·0	35·4	26·0	...
5	280·0	194·4	143·0	109·4	86·4	70·0	48·6	35·7	27·3

Transverse Strength of Steel.

Taking the ordinary standard of ultimate tensile strength, 32 tons per square inch, for steel, the formula for its ultimate transverse strength is :—

Ultimate Transverse Strength of Steel Beams of Rectangular Section, supported at the Ends, loaded at the Middle.

$$W = \frac{37{\cdot}3 bd^2}{l} \quad . \quad . \quad . \quad . \quad . \quad (84)$$

For some other values of tensile strength, the numerical coefficients annexed are to be substituted in this equation :—

Ultimate Tensile Strength. Tons.	Coefficient.
28	32·7
30	35·0
35	40·8
40	46·7
45	52·5
50	58·4

The proper coefficient for any other tensile strength is found by multiplying the strength in tons per square inch by 1·167.

Elastic Deflection of Steel Bars or Beams, of Rectangular Section, supported at the Ends, Loaded at Middle.

Square . . . $D=\dfrac{Wl^3}{56{,}000bd^2}$ . . . . . (85)

Round . . . $D=\dfrac{Wl^3}{38{,}000bd^2}$ . . . . . (86)

Ultimate Torsional Strength of Steel Bars or Shafts.

Round bar or shaft . $WR=6{\cdot}27d^3$ . . . . . (87)

" " " . $d={\cdot}252\sqrt[3]{WR}$ . . . . . (88)

Square bar or shaft . $WR=8{\cdot}99b^3$ . . . . . (89)

" " " . $b={\cdot}223\sqrt[3]{WR}$ . . . . . (90)

Elastic Torsional Deflection of Steel Bars or Shafts.

$$D=\frac{WRl}{152d_4} \quad . \quad . \quad . \quad . \quad (91)$$

TENSILE STRENGTH OF COPPER, LEAD, ETC.

	Tons per Square Inch.
Cast copper	8½ to 11½
Wrought copper	15
Copper bolts	16
Copper bolts, with 1 per cent. of phosphorus	7·56 to 19·20
" " 2 " " "	20·25
" " 3 " " "	21·38
" " 4 " " "	22·32

Solid drawn copper tube, 10 inches in diameter, ¼ inch thick (Broughton Copper Company):—

	Tons per Square Inch.
Unannealed (elastic limit, 16·34 tons per square inch)	18·64
Annealed („ 5·26 „ „)	15·35

Brazed copper tubes (Mr. Mallison):—

	Tons per Square Inch.
Plain sheet used for steam pipes (35·7 per cent. extension)	14·81
Brazed and hammered (13·83 „ „)	14·49
Brazed, not hammered (17·14 „ „)	13·47

Drawn copper tubes, 3 inches in diameter, ·131 inch to ·093 inch thick (Goodwin & How):—

	Tons per Square Inch.
Unannealed, longitudinally (extension 16·9 per cent.)	18·6
„ transversely („ 15·2 „)	18·3
Annealed, longitudinally („ 38·0 „)	14·7
„ transversely („ 35·2 „)	14·9

Elmore's deposited copper tubes (Goodwin & How):—

	Tons per Square Inch.
Unannealed, longitudinally (extension 15·5 per cent.)	17·6
„ transversely („ 6·6 „)	14·0
Annealed, longitudinally („ 27·6 „)	13·7
„ transversely („ 12·5 „)	9·6

Tensile strength of copper steam pipe at different temperatures:—

Brazed joints at 150° F. No reduction of strength when cold.
„ „ 370° to 390° F., 80 per cent. of „ „
Solid plate „ „ „ „ „ „

Cold planishing: increase of strength:—

Solid plate, cold, ¾ per cent.
„ „ hot (from 330° to 410°) 5 per cent.
Joint, cold, 17½ per cent.
„ hot, 11½ „

Strength the same, longitudinally and transversely.

Brazed joint in plain sheet, with care in workmanship, parts of solid joint, 75 per cent.

Brazed joint in pipe, under steam of 150lb. pressure, 60 to 62 per cent.

Brazing metal: spelter, 49·15 per cent., copper, 58·85 per cent

Tensile Strength of Alloys of Copper.

Aluminium bronze, castings:—

			Tons per Square Inch.
Copper 89,	aluminium 11	(extension, 0 to 5 per cent.)	45 to 50
„ 90,	„ 10	(„ 4 to 25 „)	40 to 32
„ 95,	„ 5.	(„ 35 to 50 „)	15 to 21
„ 97½,	„ 2½	(„ 45 to 60 „)	12 to 15
„ 98¾,	„ 1¼	(„ 20 to 35 „)	9 to 12

	Tons per Square Inch.
Aluminium brass, castings :—	
No. 1. Aluminium bronze, and zinc (extension, 10 to 14 per cent.)	23 to 27
No. 2. Aluminium bronze, and zinc (extension, 8 to 11 per cent.)	36 to 38
Brass, fine or yellow, 2 copper, 1 zinc	12·90
Brass tube, 62 copper, 38 zinc	46
„ „ 70 „ 30 „	36
Muntz metal, 60 copper, 40 zinc	22
Bronze, ordinary (extension, 1·2 to 4 per cent.)	9·06 to 10·58
Delta metal : Copper $\frac{2}{3}$, zinc $\frac{1}{3}$, with 2 per cent. of iron :—	
Cast in sand (extension, 21·6 per cent.)	20·9
Hard rolled, 1½-inch bars („ 34·7 „)	33·9
„ annealed („ 19·1 „)	29·8
Forged at dark red heat	36
Hammered or rolled cold upwards of	40
Gun metal, 12 copper, 1 tin	12·94
„ 11 „ 1 „	13·71
„ 10 „ 1 „	14·73
„ 9 „ 1 „	17·00
Manganese bronze: copper 88, tin 10, iron and manganese, 2 :—	
Cast under pressure (extension, 12·4 to 22 per cent.)	31·9 to 35
Rods rolled hot, annealed („ 33·4 to 44·6 „)	29
Rods rolled hot, from rolls („ 23·3 to 26·5 „)	31·5
Rods rolled hot, finished cold („ 11·6 „)	39·6
Plates rolled hot, annealed, with fibre („ 28·8 to 47·8 „)	30·10
Plates rolled hot, annealed, across fibre („ 23·2 to 34·1 „)	28·5 to 30·8
Phosphor-bronze („ 3·6 to 33·4 „)	9·7 to 22·7
Sterro-metal (Dr. Anderson) :—	
Copper 10, iron 10, zinc 80	3·17
„ 60, „ 3, „ 39, tin, 1·5	24
„ 60, „ 4, „ 44, „ 2 :—	
Cast in sand	19·25
Cast in iron, annealed	24·25
Cast in iron, forged red hot	31

	Tons per Sq. In.
Copper 60, iron 2, zinc 37, tin 1	34
,, 60, ,, 2, ,, 35, ,, 2	38
,, 55, ,, 1·77, ,, 42·36 ,, ·83 :—	
Cast	27
Forged red hot	34
Drawn cold	38

Ultimate Tensile Strength of Lead, Tin, Zinc, and Glass.

	Tons per Sq. In.
Lead, cast	·81
,, sheet	·86
,, pipe	1·00
Tin, cast	2·11
,, banco	·95
,, solder, soft (2 tin, 1 lead)	3·35
Zinc, cast	1·34
,, sheet, with grain (London Zinc Mills) (extension, 14·2 per cent.)	14·6
Glass, flint, annealed	1·07
,, green	1·29
,, crown	1·14
,, thin globes	2·23

TABLE 195.—ULTIMATE TENSILE STRENGTH OF WIRES.

(Mr. Kirkaldy.)

Wires from $\frac{1}{13}$ to $\frac{1}{17}$ inch thick, except Phosphor bronze, $\frac{1}{8}$ inch thick.

Wire.	Ultimate Tensile Strength per Square Inch.		Extension, annealed.	Twists in Five Inches of Length.	
	Unannealed.	Annealed.		Unannealed.	Annealed.
	Tons.	Tons.	Per cent.	Twists.	Twists.
Coke iron	28·71	27·36	17	26	44
Charcoal iron	29·05	23·99	28	48	87
Steel	54·07	33·32	10·9	*	79
Copper	28·18	16·52	34·1	86·8	96
Brass	36·23	23·01	36·5	14·7	57
Phosphor bronze, No. 1	71·21	26·27	46·6	13·3	66
,, No. 2	67·46	28·86	42·8	15·8	60
,, No. 3	62·12	24·15	44·9	17·3	53
,, No. 4	53·98	23·83	42·4	13	124

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* Of the eight pieces of steel tested, 3 stood 40 to 45 turns, and 5 stood 1½ to 4 turns.

TABLE 196.—COMPARATIVE TENACITY OF METAL WIRES AT DIFFERENT TEMPERATURES.

The wires tested were about $\frac{1}{80}$th inch thick, except the iron wires, which were $\frac{1}{115}$th inch thick.

	Tons per Square Inch.		
	At 32° F.	At 212° F.	At 392° F.
Gold	11·90	9·85	8·25
Platinum	14·50	12·60	11·25
Copper	18·20	15·90	13·75
Silver	18·05	15·20	11·85
Palladium	23·30	20·75	17·85
Iron	131·75	124·70	134·5

The steel wire, $\frac{1}{10}$ inch thick, of the Brooklyn cable railway, was proved to an average ultimate tensile strength of 70·40 tons per square inch, with an extension of 7·3 per cent.

RESISTANCE OF STONES AND OTHER BUILDING MATERIALS.

TABLE 197.—RESISTANCE OF STONES TO CRUSHING STRESS.

(Fairbairn.)

Stone.	Cube.	Fractured at.	Crushed at.	Crushing Force	
				Per Sq. In.	[illegible]
	Inches.	Tons.	Tons.	Tons.	[illegible]
Greywacke, Penmaenmaur	2	18·1	30·2	7·5	[illegible]
Granite, Mount Sorrel .	2	22·9	22·9	5·7	[illegible]
Syenite ,, . . .	2	21·1	21·1	5·3	[illegible]
Granite, Bonar, Inverary .	$1\frac{1}{2}$	7·8	10 9	4·9	[illegible]
Limestone	$1\frac{1}{2}$	7·7	8·6	3·8	[illegible]
Sandstone	1	1·4	1·6	1·6	[illegible]
,, ...	2	4·6	5·5	1·4	[illegible]
Victoria Stone (granite and Portland cement, steeped in a solution of flint).				3·71	[illegible]

TABLE 197.—RESISTANCE OF STONES TO CRUSHING STRES (*continued*).

(L. Clark.)

RED SANDSTONE, average weight, 130·6 lbs. per cubic foot; 17 cubic feet per ton.

Specimen.	Cube.	Crushing Load.	Load per Sq. In.	Load per Sq. Ft.
	Inches.	Tons.	Tons.	Tons.
No. 6. Quite dry, set between boards	3	8·21	·91	131·0
No. 7. Set in cement, moderately damp	3	5·16	·57	82·1
No. 8. Set in cement, very wet . .	3	4·36	·48	69·1
No. 9. Set in cement	6	63·07	1·75	252·0
Average	. . . .	. .	·93	133·8

Note.—Gave way suddenly.

ANGLESEA LIMESTONE. Weight, 165·25 lbs. per cubic foot; 13½ cubic feet per ton.

Specimen.	Cube.	Crushing Load.	Load per Sq. In.	Load per Sq. Ft.
No. 11. Set between boards . .	3	26·58	2·95	424·8
No. 12. ,, ,, began to crack at 25 tons . . .	3	32·30	3·60	518·4
No. 13. Set between boards . . .	3	30·95	3·44	495·4
No. 14. Three separate 1 inch cubes set between boards	...	9·37	3·12	449·3
Average	. . .	. .	3·28	472·3

(Debauve.)

	Weight per Cubic Foot.	Crushing Force per Sq. Inch.	Crushing Force per Sq. Foot.
	Pounds.	Tons.	Tons.
Granite: hard, fine grain . .	..	6·4 to 9·6	922 to 1382
,, ,, coarse grain . .	...	4·4 to 6·4	634 to 923
,, slowly decomposes in water:			
fine grain	..	3·8 to 5·7	547 to 821
coarse grain	...	2·5 to 3·8	360 to 547
Basalt	...	12·1	1742
Lava	112·3	2·7	389
Porphyry	...	8·2	1181
Jasper	...	11·7	1685
Sandstone: hard	131 to 156	2·2 to 4·9	317 to 706
,, semi-hard, or tender .	118·5 to 131	·51 to 1·9	73 to 274
Limestone: for building . . .	87·4 to 174·7	·13 to 7·6	19 to 1094
,, hard	137 to 175	1·4 to 7·6	202 to 1094
,, soft	87·4 to 137	·51 to 1·4	73 to 202

TABLE 198.—RESISTANCE OF SLATES TO RUPTURE.

(Debauve.)

Pieces of Anjou slate, 10 inches square, resting by their four edges on a flat frame bearing, were loaded on a central space 4 inches square.

Thickness.		Breaking Load.		Thickness.		Breaking Load.	
Millims.	Inch.	Kilogrs.	Pounds.	Millims.	Inch.	Kilogrs.	Pounds.
1	·0394	8	17·6	5	·1968	120	264
2	·0787	35	77	6	·2362	150	330
3	·1181	50	110	7	·2756	170	374
4	·1575	90	198				

TABLE 199.—RESISTANCE OF BRICKS AND BRICKWORK TO CRUSHING STRESS.

Description.	Crushing Force per Square Inch.	Crushing Force per Square Foot.
	Tons.	Tons.
Red	·358	51·6
Yellow-faced, baked	·446	64·2
„ burned	·643	92·6
Gault clay, pressed	1·111	160
„ wire-cut	·884	127·3
„ perforated	1·180	169·9
Stock	1·044	150·3
Fareham red	2·500	360
Staffordshire blue, pressed with frogs	3·100	446·4
„ rough, without frogs	3·275	471·6
„ Hamblet's (Kirkcaldy)	7·390	824
Stourbridge fireclay	·718	103·4
Tividale blue	·620	89·3
Silex ferrine	7·332	1056·2
Vitrified granite, Candy's	3·091	445·2
Terra-cotta fire and sound proof (before cracking)	·315	45·3
Glass	12·31 to 14·23	1773

TABLE 199.—RESISTANCE OF BRICKS AND BRICKWORK T CRUSHING STRESS (*continued*).

Cemented Brickwork. Best quality.

	Cube.	Weight.	Crushing Load.	Load per Square Inch.	Load per Squar Foot.
	Inches.	Pounds.	Tons.	Tons.	Tons.
No. 1, 9-inch cube set between deal boards	9	54	19·94	·25	36·0
No. 2, 9-inch cube in cement	9	53	22·15	·27	38·9
No. 3, 9-inch cube in cement	9	52	16·42	·20	28·8
No. 4, $9\frac{1}{4}$-inch cube in cement	$9\frac{1}{4}$	$55\frac{1}{2}$	21·72	·27	38·9
No. 5, 9-inch cube, between boards	9	$54\frac{1}{4}$	15·50	·19	27·4
Average	. . .	. . .	. . .	·23	34·0

Note.—Irregular cracks occurred a considerable time before the blocks gave way.

TABLE 200.—RESISTANCE OF PORTLAND CEMENT CONCRET BLOCKS TO CRUSHING STRESS.

(Grant.)

Portland Cement Concrete Blocks: 12 inch cubes compressed, 12 months old.

	Cube.	Weight.	Crushing Load.	Load per Square Inch.	Load per Squar Foot.
	Inches.	Pounds.	Tons.	Tons.	Tons.
1 cement to 1 sand and gravel	12	...	170·5	1·18	170·5
3 „	12	...	115·5	·81	115·5
6 „	12	...	91·0	·63	91·0

TABLE 201.—ULTIMATE TENSILE STRENGTH OF STONES. (Debauve.)

Stone.	Tensile Resistance per Square Inch.	Tensile Resistance per Square Foot.
	Tons.	Tons.
Basalt (Auvergne)	·49	70·6
Portland limestone	·38	54·7
Compact ,,	·20	29
Silicious ,,	·14	20·2
Oolitic ,,	·09	13
Brick of good quality	·11 to ·13	16·8 to 18·7
Bagneux rock (near Paris)	·09	13
Soft stone (le Vergelet)	·045	6·5
Stoneware pipes	21lb. to 350lb. or ·15 ton.	1·35 to 21·6

TABLE 202.—**Average Working Loads for Building Materials and Structures** (Austrian Association of Engineers).

(1) WEIGHT OF MATERIALS.

Material.		Lbs. per Cubic Foot.
TIMBER :—		
Oak		50
Pine		44
Fir		44
Red pine		41
Pitch pine		
Larch		44
METAL :—		
Wrought iron (per cubic inch, ·28 lb.)		490
Cast iron (,, ·27 lb.)		468
Lead (,, ·40 lb.)		711
Copper (,, ·32 lb.)		555
Zinc (,, ·26 lb.)		449
BRICK AND STONE :—	(Wet.)	(Dry.)
Hollow bricks	87	75
Ordinary ,,	106	94
Flemish ,,	125	119
Rubble Masonry		150
Concrete		150
Ashlar sandstone		150 to 156
,, limestone		162 to 169
Granite		175

TABLE 202.—(1) WEIGHT OF MATERIALS (*continued*).

Material.	Lbs. per Cubic Foot.
VARIOUS MATERIALS:—	
Broken stone	87
Fine dry sand	77
Coarse dry sand	84
Clay, loam, dry	94
„ wet	119
Lime mortar, cement mortar	106
Asphalte, pure	69
„ concrete	100
„ compressed	113
Gypsum	72
Window glass	165

TABLE 202.—(2) WORKING STRESS.

Material.	Tensile, per Square Inch.	Compressive, per Square Inch.
	Tons.	Tons.
Wrought iron	6·0	6·0
Cast iron	1·5	4·5
Oak	·60	·42
Pine	·54	·36
Fir	·42	·36
Red pine	·42	·33
Larch	·42	·33

TABLE 202.—(3) WORKING LOADS ON FOUNDATIONS.

Foundation.	Tons per Square Foot.
Moist clay and sand (protected against lateral spreading)	1·36
Coarse sand and dry clay	2·27
Firm bedded broken stones on dry clay	3·18
Loose impermeable beds, with piling	1·82
„ „ „ and concrete	2·73

TABLE 202.—(4) WORKING LOAD ON STONE WALLS AND COLUMNS.

Material.	Thick Ashlar walls and single bed-stones and columns, where diameter is not less than half the height.	Block-in-course work and columns where diameter is from half to one-twelfth of height.	Columns where diameter is less than one-twelfth of height.
	Lbs. per Sq. Inch.	Lbs. per Sq. Inch.	Lbs. per Sq. Inch.
Granite, porphyry	712	570	285
Hard stone	356	285	...
Medium stone	214	142	...
Soft stone	108	...	...

TABLE 202.—(5) WORKING LOADS ON BRICKWORK, MASONRY, &C.

Description of Work.	Walls not less than 18 inches thick, and columns where diameter is not less than one-sixth of height.	Walls under 18 inches thick, and columns where diameter is from one-sixth to one-eighth of height.	Columns where diameter is from one-eighth to one-twelfth of height.
	Lbs. per Sq. Inch.	Lbs. per Sq. Inch.	Lbs. per Sq. Inch.
Brickwork in lime mortar	72	36	...
" cement "	108	72	...
" Portland cement	142	108	44
Rubble masonry in lime mortar	58	...	...
" cement "	72	...	...
Pressed bricks in " "	128	114	108
" Portland cement	172	142	114
Flemish bricks in "	214	172	142
Portland cement concrete	100	...	...

TABLE 202.—(6) WORKING LOADS ON FLOORS, STAIRS, AND ROOFS.

Location.	Lbs. per Square Foot.
Live loads on floors :—	
Attic floors	30·8
Dwelling-room floors	51·2
Libraries, dancing saloons, &c.	71·7
Stairs and passages	82·0
Business premises, workrooms, &c.	92·2
Hay and fruit lofts	102·5
Workshops and warehouses	112·7
Theatres, concert rooms, warehouses and workshops with heavy machinery or special loads	Loads specially adapted.

Dead loads, snow and wind, on roofs—in lbs. per square yard on horizontal plane :—

	Slope of Roof.	Dead Load.	Snow and Wind.	Total.
		Lbs.	Lbs.	Lbs.
Single tile roof	1 horizontal to 1·25 vertical	27·7	25·6	53·3
Double "	1 to 1·25	33·8	25·6	59·4
Single slate	1 " 2·25	15·4	19·5	34·9
Double "	1 " 2·25	23·6	19·5	43·1
Zinc or galvanised iron	1 " 4	8·2	15·4	23·6
Carton-Pierre	1 " 4	8·2	15·4	23·6
Sheet iron or iron purlins	1 " 5	4·1	15·4	19·5

TABLE 202.—(7) SNOW AND WIND.

Weight of snow on horizontal surface	allow 15·5 lbs. per sq. foot.
Wind pressure on surface at right angles to line of impact	" 24·6 " "
Do. do. in specially exposed positions	" 31·0 " "

RIVETED JOINTS IN BOILER PLATES.

The proportion by which maximum strength of riveted joints is attained, are given in Table 203, in terms of thickness of plates and diameter of rivets.

TABLE 203.—PROPORTIONS OF RIVETED JOINTS OF MAXIMUM STRENGTH.

thickness of plates . . . = unity
diameter of rivets . . . = thickness of plate × 2.
pitch of rivets (single riveting) . . . . . = thickness of plate × 5⅓. = diameter of rivets × 2⅔
pitch of rivets (double riveting) . . . . = thickness of plates × 8. = diameter of rivets × 4.
diagonal pitch (double riveting) . . . . = longitudinal pitch × ¾. = diameter of rivets × 3
" spacing " (double riveting) = longitudinal pitch × ·56, or $\frac{9}{16}$.
lap (single riveting) . . = thickness of plate × 6 = diameter of rivets × 3
lap (double riveting) . . . = thickness of plate × 10·48, or 10½ = diameter of rivets × 5·24, or 5¼.

In conformity with the above proportions, the upper part of the following Table 204, shows the dimensions of rivet-joints in plates from ⅛ inch to $\frac{11}{16}$ inch thick, for the last of which 1⅜ inch rivets are provided. This is the largest size of rivets ordinarily used in boiler construction. For plates thicker than $\frac{11}{16}$ inch, the joints are to be made with 1⅜ inch rivets, suitably pitched, for equal resistance of net section of plate and shearing resistance of rivets; and, therefore, for maximum strength when 1⅜ inch rivets are used, as given in the lower part of the Table.

For boiler plates of iron and of steel ⅜ inch in thickness, the breaking or ultimate strength of riveted joints in parts of that of the entire plate, are given in the Table 205. These relative values are deduced from the results of numerous experimental tests. The nominal diameter of rivets—not that of the rivet-holes—is adopted in calculation.

The percentage of breaking strength in the last two columns of Table 205 may be adopted for other thicknesses of plate up to $\frac{11}{16}$ inch, as in Table 204, upper part; except the values for single-riveted lap and singlewelt, which for thinner than ⅜ inch plates are higher; and for thicker plates are lower. For plates thicker than $\frac{11}{16}$ inch, as in the lower part of Table 204, the breaking strengths may be taken as approximately in the proportion of the net sections of plate as percentages of the entire section. These are here subjoined in Table 206 :—

TABLE 204.—DIMENSIONS OF RIVET JOINTS.
(Plates $\frac{1}{8}$ inch to $\frac{11}{16}$ inch thick).

Thickness of Plates.	Diameter of Rivets.	Pitch of Rivets.				Lap.	
		Single-Riveting.	Double Riveting.			Single-Riveting.	Double-Riveting.
			Longitudinal.	Diagonal.	Spacing.*		
Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.
$\frac{1}{8}$	$\frac{1}{4}$	$\frac{2}{3}$	1	$\frac{3}{4}$	$\frac{9}{16}$	$\frac{3}{4}$	$1\frac{5}{16}$
$\frac{3}{16}$	$\frac{3}{8}$	1	$1\frac{1}{2}$	$1\frac{1}{8}$	$\frac{27}{32}$	$1\frac{1}{8}$	2
$\frac{1}{4}$	$\frac{1}{2}$	$1\frac{1}{3}$	2	$1\frac{1}{2}$	$1\frac{1}{8}$	$1\frac{1}{2}$	$2\frac{5}{8}$
$\frac{5}{16}$	$\frac{5}{8}$	$1\frac{2}{3}$	$2\frac{1}{2}$	$1\frac{7}{8}$	$1\frac{13}{32}$	$1\frac{7}{8}$	$3\frac{1}{4}$
$\frac{3}{8}$	$\frac{3}{4}$	2	3	$2\frac{1}{4}$	$1\frac{11}{16}$	$2\frac{1}{4}$	$3\frac{15}{16}$
$\frac{7}{16}$	$\frac{7}{8}$	$2\frac{1}{3}$	$3\frac{1}{2}$	$2\frac{5}{8}$	2	$2\frac{5}{8}$	$4\frac{5}{8}$
$\frac{1}{2}$	1	$2\frac{2}{3}$	4	3	$2\frac{1}{4}$	3	$5\frac{1}{4}$
$\frac{9}{16}$	$1\frac{1}{8}$	3	$4\frac{1}{2}$	$3\frac{3}{8}$	$2\frac{1}{2}$	$3\frac{3}{8}$	$5\frac{7}{8}$
$\frac{5}{8}$	$1\frac{1}{4}$	$3\frac{1}{3}$	5	$3\frac{3}{4}$	$2\frac{13}{16}$	$3\frac{3}{4}$	$6\frac{1}{2}$
$\frac{11}{16}$	$1\frac{3}{8}$	$3\frac{2}{3}$	$5\frac{1}{2}$	$4\frac{1}{8}$	$3\frac{1}{16}$	$4\frac{1}{8}$	$7\frac{1}{4}$
$\frac{3}{4}$	$1\frac{3}{8}$	3·475	5·156	3·867	2·900	$4\frac{1}{8}$	$7\frac{1}{4}$
$\frac{13}{16}$	$1\frac{3}{8}$	3·318	4·866	3·650	2·737	$4\frac{1}{8}$	$7\frac{1}{4}$
$\frac{7}{8}$	$1\frac{3}{8}$	3·179	4·616	3·462	2·597	$4\frac{1}{8}$	$7\frac{1}{4}$
$\frac{15}{16}$	$1\frac{3}{8}$	3·059	4·401	3·301	2·475	$4\frac{1}{8}$	$7\frac{1}{4}$
1	$1\frac{3}{8}$	2·953	4·212	3·159	2·370	$4\frac{1}{8}$	$7\frac{1}{4}$
$1\frac{1}{16}$	$1\frac{3}{8}$	2·860	4·045	3·034	2·275	$4\frac{1}{8}$	$7\frac{1}{4}$
$1\frac{1}{8}$	$1\frac{3}{8}$	2·778	3·895	2·921	2·191	$4\frac{1}{8}$	$7\frac{1}{4}$

TABLE 205.—ULTIMATE RELATIVE STRENGTH OF RIVETED JOINTS IN $\frac{3}{8}$-INCH BOILER PLATES.

$\frac{3}{8}$-inch Plate Joint.	Thickness of Plate.	Rivets.		Nominal net section of plate in parts of that of whole plate.	Breaking Strength in Parts of that of Whole Plate.	
		Diameter.	Pitch longitudinally.		Iron.	Steel.
	Inch.	Inch.	Inches.	Per cent.	Per cent.	Per cent.
Single-riveted lap .	$\frac{3}{8}$	$\frac{3}{4}$	2	62·5	56	60
,, single welt	$\frac{3}{8}$	$\frac{3}{4}$	2	62·5	50	58
,, double welt	$\frac{3}{8}$	$\frac{3}{4}$	2	62·5	60	65
Double-riveted lap .	$\frac{3}{8}$	$\frac{3}{4}$	3	75	70	80
,, single welt	$\frac{3}{8}$	$\frac{3}{4}$	3	75	65	78
,, double welt	$\frac{3}{8}$	$\frac{3}{4}$	3	75	72	80

* *Note* "Spacing" is the pitch of the longitudinal centre-lines of rivets in double-riveted joints.

TABLE 206.—NET PLATE SECTION OF PLATES $\frac{3}{4}$ INCH AND UPWARDS IN THICKNESS.

Thickness of Plate.	Diameter of Rivets.	Net Plate Section in parts of Whole Section.	
		Single Riveting.	Double riveting.
Inches.	Inches.	Per cent.	Per cent.
$\frac{3}{4}$	$1\frac{3}{8}$	60·4	73·5
$\frac{13}{16}$	$1\frac{3}{8}$	58·6	71·7
$\frac{7}{8}$	$1\frac{3}{8}$	56·8	70·2
$\frac{15}{16}$	$1\frac{3}{8}$	55·0	68·8
1	$1\frac{3}{8}$	53·4	67·4
$1\frac{1}{16}$	$1\frac{3}{8}$	51·9	66·0
$1\frac{1}{8}$	$1\frac{3}{8}$	50·5	64·7

The most suitable pitches for given diameters of rivets, or, on the contrary, the most suitable diameters of rivets for given pitches, in order to form joints of equal resistance, may be calculated by means of the following formulæ (92) and (93), as, of course, pitches and diameters may be adopted other than those which are above-recommended :—

single riveted lap joint :—

$$p = \cdot 835\frac{d^2}{t} + d \quad . \quad . \quad (92)$$

$$d = \sqrt{1\cdot 20\,t\,p + \cdot 36\,t^2} - \cdot 60\,t \;.\; (93)$$

These formulæ are applicable also for single-riveted single-welt and double-welt joints.

double-riveted lap joints :—

$$p = 1\cdot 5\frac{d^2}{t} + d \quad . \quad . \quad . \quad (94)$$

$$d = \sqrt{\frac{2}{3}\,t\,p + \frac{t^2}{9}} - \frac{t}{3} \quad . \quad (95)$$

These formulæ are applicable also for double-riveted single-welt and double-welt joints.

BOILER SHELLS.

The bursting strength per square inch of a cylindrical boiler shell is twice as much longitudinally, that is to say, parallel to the axis, as it is transversely.

Bursting pressure $p = \dfrac{4480ts}{d}$ . . . . . (96)

thickness of plates $t = \dfrac{dp}{4480s}$ . . . . . . (97)

ultimate tensile strength of plates $s=\frac{dp}{4480t}$ . . (98)

d = internal diameter, in inches.
t = thickness of plate, in inches.
s = ultimate tensile strength of plate, in tons per square inch.
p = effective steam pressure, in pounds per square inch.

When the shell is constructed with riveted joints, the tensile strength s is to be reduced in the ratio of the ultimate strength of the whole plate to that of the joint.

The resistence of a hollow sphere to internal pressure is twice as much as that of a tube of equal diameter and equal thickness.

Strength of Ends of Cylindrical Steam Boilers.

For a flat end-plate forming the termination of a cylindrical shell, unstayed or unsupported except at the circumference, the ultimate elastic deflection under internal pressure is given by the formulæ :—

$$\delta=\frac{\text{radius}}{22}=\frac{r}{22} \quad . \quad . \quad . \quad (99)$$

$$\delta=\frac{\text{diameter}}{44}=\frac{d}{44} \quad . \quad . \quad . \quad (100)$$

δ = deflection at the centre in inches.
r = radius of the cylinder, in inches.
d = diameter of the cylinder in inches.

The relative internal pressure and stress in the end-plate strained to the elastic limit, are given by this formula :—

$$p=\frac{815ts}{d} \quad . \quad . \quad . \quad . \quad (101)$$

p = effective internal pressure, in lbs. per square inch.
t = thickness of end-plate, in inches.
s = tensile stress in end-plate, in tons per square inch at the elastic limit.

This formula is applicable for steel plates, as for iron plates, taking the elastic limit to be the same for both metals, namely, $\frac{1}{1000}$th of the length. The elastic strength, s, is, for iron, 12 tons; for steel 14 tons per square inch. Substituting these values in formula (101), the final formulæ are derived for the elastic strength of circular flat end-plates of iron and of steel, of uniform thickness, fastened at the circumference, exposed to bulging pressure uniformly distributed :—

for iron, $$p=10{,}000\,\frac{t}{d} \qquad (102)$$

for steel, $$p=11{,}500\frac{t}{d} \qquad (103)$$

p = bulging pressure, in lbs. per square inch.
t = thickness of the plate, in inches.
d = diameter of the plate, in inches, measured to the circular line of junction.

Flat Cast-iron Ends.

The elastic strength of flat cast-iron ends, adopting an extension of $\frac{1}{1000}$th part of the length, as for iron and steel, corresponding to a tensile stress of 5 tons per square inch, is expressed by the formulæ :—

$$\delta=\frac{d}{44} \qquad (104)$$

$$p=4000\frac{t}{d} \qquad (105)$$

δ = deflection at centre, within the elastic limit, in inches.
d = diameter of the line of fastening, in inches.
t = thickness of the plate in inches.
p = elastic bulging pressure, in lbs. per square inch, uniformly distributed.

For cast-iron of stronger quality, the co-efficient in formula (105) is to be increased in proportion.

Segmental Ends.

The relation of the internal pressure and stress in a segmental or spherical end of a cylindrical shell, is given by the formula :—

$$p=\frac{8960ts}{\frac{r^2}{v}+v} \qquad (106)$$

p = internal pressure, in lbs. per square inch.
t = thickness of segmental end, in inches.
s = tensile stress in the plate, in tons per square inch.
r = radius of the circular junction, in inches.
v = versed sine or rise of the segment, in inches.

Substituting for the values of s : 12 tons for wrought iron, 14 tons for steel, and 5 tons for cast iron, the formula becomes :—

Wrought iron, $$p=\frac{108{,}000t}{\frac{r^2}{v}+v} \quad . \quad . \quad . \qquad (107)$$

Steel, $$p=\frac{125{,}000t}{\frac{r^2}{v}+v} \quad . \quad . \quad . \quad . \qquad (108)$$

Cast-iron, $$p=\frac{45{,}000t}{\frac{r^2}{v}+v} \quad . \quad . \quad . \quad . \qquad (109)$$

The versed sine or rise at the centre of a spherical segment having the same elastic strength as the body of the cylinder, measured by the internal pressure, is, say, one-fourth of the radius of the end of the cylinder, or one-eighth of its diameter.

Strength of stayed flat plates of steam boilers.

The relative internal pressure and stress in a flat-stayed plate, strained to the elastic limit, are given by the formula :—

$$p=\frac{407ts}{d} \quad . \quad . \quad . \quad . \qquad (110)$$

p = internal pressure in lbs. per square inch.
t = thickness of the plate in inches.
d = clear distance apart between the bolts in rectangular arrangement.
s = tensile stress in the plate, in tons per square inch, at the elastic limit.

When the pitches of the staybolts, vertically and transversely, are not equal to each other, the greater clear distance is to be taken for calculation.

Reducing the above formula (110) for iron and for steel plates, of which the values of s are taken as 12 tons and 14 tons respectively, and also inverting the formulæ to find the thickness of plate, and the clear distance apart of the staybolts, the following formulæ are obtained :—

For Iron.	For steel.	
$p=5{,}000\frac{t}{d}$	$p=5{,}700\frac{t}{d}$	(111)
$t=\frac{pd}{5{,}000}$	$t=\frac{pd}{5{,}700}$	(112)
$d=\frac{5{,}000t}{p}$	$d=\frac{5{,}700t}{p}$	(113)

The proper diameter of screwed stay bolts, at the base of the thread, strained to the elastic limit, simultaneously with the plate, is given by formula :—

$$d' = \cdot 0024 \sqrt{\frac{P\,P'\,p}{s}} \quad . \quad . \quad . \quad (114)$$

d' = diameter of staybolts, at base of thread.
P = pitch of staybolts between centres, longitudinally.
P′ = ,, ,, ,, transversely.
p = maximum effective elastic pressure, in lbs. per square inch, on the plate.
s = elastic tensile strength of staybolts, in tons per square inch.

For bolts of iron, steel, and copper, having respectively 12 tons, 14 tons, and 8 tons, elastic tensile strength per square inch, the special formulæ for the proper diameter of the staybolts, at the base of the thread, are :—

$$\text{Iron } d' = \cdot 00069 \sqrt{P\,P'\,p}\,;\ \text{or } d' = \frac{\text{When } P' = P}{\cdot 00069} P \sqrt{p} \quad (115)$$

$$\text{Steel } d' = \cdot 00064 \sqrt{P\,P'\,p}\,;\ \text{or } d' = \cdot 00064\, P \sqrt{p} \quad . \quad (116)$$

$$\text{Copper } d' = \cdot 00084 \sqrt{P\,P'\,p}\,;\ \text{or } d' = \cdot 00084\, P \sqrt{p} \quad . \quad (117)$$

Collapsing Resistance of furnace-tubes.

Plain furnace-tubes of Lancashire and Cornish steam-boilers, without stiffening joints, have the maximum resistance to collapsing pressure under steam, according to the formula :—

$$p = \frac{200{,}000\, t^2}{d^{1 \cdot 75}} \quad . \quad . \quad . \quad . \quad (118)$$

p = collapsing pressure, in lbs. per square inch.
t = thickness of the plates of the furnace-tube in inches.
d = internal diameter of the furnace tube in inches.

This formula is applicable to furnace-tubes of lengths of over 9 feet. Tubes of shorter length derive natural assistance from the end fastenings.

Segmental Crowns of furnaces.

The elastic resistance of a segmental crown of a cylindrical furnace, to collapsing pressure externally may be formulated in the same terms as the resistance to bursting pressure internally, here repeated :—

$$p=\frac{8960\,t\,s}{\frac{r^2}{v}+v} \quad . \quad . \quad . \quad . \quad . \quad . \quad (119)$$

t = thickness of plate, in inches.
r = radius of circular junction, in inches.
v = versed sine, or rise of segment, in inches.
p = external collapsing pressure, in lbs. per square inch.
s = compressive stress in the segment, in tons per square inch.

For the application of this formula, it is assumed that the spherical segment is perfectly formed. A segment of which the rise is one-eighth of the diameter of the cylindrical base is equally stressed with the base, under equal external pressure per square inch.

When the spherical segment is a hemisphere, made of plates equal in thickness to those of the cylinder, it is stressed to only half the extent per square inch to which the cylinder is stressed.

Hydraulic, Steam, and other Hollow Cylinders.

The resistance of, say, a hydraulic ram, to bursting pressure, is unequally distributed over the transverse section of the ram, being a maximum at the interior surface, diminishing radially to a minimum at the outer surface. The inequality of active resistance arises from the stretching of the material exposed to pressure, up to and beyond the elastic limit.

The formulas for resistance, in their most general form, are as follows :—

$$p=s \times \text{hyp log. R.} \quad . \quad . \quad . \quad . \quad (120)$$

$$s=\frac{p}{\text{hyp log. R.}} \quad . \quad . \quad . \quad . \quad . \quad (121)$$

$$\text{hyp log. R}=\frac{p}{s} \quad . \quad . \quad . \quad . \quad . \quad (122)$$

$$d'=d \times \text{R} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (123)$$

$$t=\frac{d\,(\text{R}-1)}{2} \quad . \quad . \quad . \quad . \quad . \quad (124)$$

d = inside diameter, in inches.
d' = outside diameter, in inches.
p = internal pressure in tons per square inch.
s = maximum tensile stress, in tons per square inch.
R = ratio of outside diameter to inside diameter, or $\frac{d}{d}$

Note.—The pressure and stress may be expressed in hundredweights or in pounds.

In cases where the internal tensional stress on the material exceeds the elastic limit, the formulas are to be taken as only approximate. But it is believed that in such cases they are substantially correct for practical purposes. They are taken as correct for maximum tensional stress not exceeding the elastic limit.

The average tensional stress on the metal is equal to $\frac{p\,d}{d' - d}$.

That is to say, it is equal in tons per square inch to the product of the inside diameter by the internal pressure in tons per square inch, divided by the difference of the inside and outside diameters.

Example.—To find the bursting pressure of a cast-iron cylinder 8 inches in diameter inside, and 25 inches outside, the ultimate tensile strength of the metal being 7 tons per square inch. The ratio of the diameters is (25 ÷ 8 =) 3·12, of which the hyperbolic logarithm is 1·1378. By formula (120), the bursting pressure is (7 × 1·1378 =) 7·96 tons per square inch. The average stress over the whole sectional area of the metal is equal to (8 × 7·96) ÷ (25 − 8) = 3·75 tons per square inch of section of metal.

2nd *Example.*—To find the bursting pressure of a hydraulic tube $1\frac{7}{8}$ inches in bore, $\frac{5}{16}$ inch thick; the direct ultimate tensile strength being 22 tons per square inch. The ratio of the outside and inside diameters is ($2\frac{1}{2} \div 1\frac{7}{8} =$) 1·33, the hyperbolic logarithm of which is ·2852. By formula (120), the bursting pressure is 6·27 tons, or 14,045 pounds per square inch. The tube had been proved to a pressure of 11,000 pounds without failure.

In cases where the diameter is considerable in relation to the thickness, the transverse resistance to bursting pressure is taken as equal to the direct tensile strength per square inch of sectional area, according to the common rules already given.

WIRE ROPES AND HEMP ROPES.

The comprehensive Tables 207 to 211, of the weight and strength of wire ropes manufactured by Messrs. Dixon & Corbitt and R. S. Newall & Co., comprise qualities varying from annealed iron having an ultimate tensile strength of 25 tons per square inch, and charcoal iron wire of 34 tons per square inch, to special or extra plough steel wire of 150 tons. The "patent steel" is crucible steel or open hearth steel hardened and tempered by a special process. The breaking strengths have been carefully ascertained. They are based on the most common system of construction:—round ropes of 6 strands of 7 wires each, or 6 strands of 6 wires each. In the first there are 6 wires over a central wire; in the second, 6 wires over a hemp core. With such proportions, the cylindrical form is best maintained, and splicing is most readily effected. But ropes are made with from 3 to 12 strands. Wires vary from ·010 inch to ·212 inch in diameter for 6-strand ropes of 7 wires in each strand. But conductor or guide-ropes of 7 wires forming a strand have been made of ⅝ inch rods.

Tables 212 and 213 give the sizes and strength of hemp ropes by Messrs. Dixon & Corbitt and R. S. Newall & Co. For the dimensions of cotton ropes, the same firm assume that cotton is equal in strength to hemp; and for coir ropes, that coir, or cocoa-fibre, is of half the strength.

For vertical winding at a high speed, they adopt one-tenth of the breaking stress as a safe working load. But the load may, with suitable working conditions, be increased to a value of one-eighth. The gross weight hanging over the pulley is taken as the working load.

For hauling, the working load is usually taken by them at one-sixth of the breaking stress; and the following form of calculation for determining the proper size of rope, has been found by experience to be satisfactory:—Take an inclined plane, say, 800 yards in length; load, 20 tons; maximum inclination of road, 7 degrees, or 1 in 8·14.

Calculation for Resistance.

	cwts.	qrs.	lbs.
Gravity of load, 20 tons × 272·98 lbs. per ton .	49	0	16
Friction of load, 20 tons × 20 lbs. per ton . .	3	2	8
Gravity of rope, 800 yards, at 2 lbs. per yard, = 1600 lbs. ÷ 8·14	1	3	1
Friction of rope, 1600 lbs. ÷ 20	0	2	24
Total working stress or load	55	0	21

TABLE 207.—ROUND WIRE ROPES: WEIGHT

Sizes.		Weights per Fathom.		Charcoal Iron.			Bessemer Steel, or Ingot Iron.			Phosphor Bronze.		
		6 Strands.			Working Load.			Working Load.			Working Load.	
Diameter.	Circumference.	7 Wires.	6 Wires.	Breaking Strain.	Pit.	Incline.	Breaking Strain.	Pit.	Incline.	Breaking Strain.	Pit.	Incline.
Ins.	Ins.	Lbs.	Lbs.	Tons.	Cwts.	Cwts.	Tons.	Cwts.	Cwts.	Tons.	Cwts.	Cwts.
$\frac{11}{32}$	$1\frac{1}{8}$	1·2	1·1	1·9	3	5	2·2	4	7	2·2	4	7
$\frac{3}{8}$	$1\frac{1}{4}$	1·5	1·3	2·2	4	7	2·6	5	8	2·6	5	8
$\frac{13}{32}$	$1\frac{3}{8}$	1·8	1·6	2·7	5	9	3·2	6	10	3·2	6	10
$\frac{15}{32}$	$1\frac{1}{2}$	2·1	1·9	3·3	6	11	3·8	7	12	3·8	7	12
$\frac{1}{2}$	$1\frac{5}{8}$	2·5	2·3	4·0	8	13	4·6	9	15	4·6	9	15
$\frac{9}{16}$	$1\frac{3}{4}$	2·9	2·6	4·5	9	15	5·2	10	17	5·2	10	17
$\frac{19}{32}$	$1\frac{7}{8}$	3·3	3·0	5·2	10	17	6·0	12	20	6·0	12	20
$\frac{5}{8}$	2	3·8	3·5	6·2	12	20	7·0	14	23	7·0	14	23
$\frac{11}{16}$	$2\frac{1}{8}$	4·3	4·0	7·0	14	23	8·0	16	26	8·0	16	26
$\frac{23}{32}$	$2\frac{1}{4}$	4·8	4·4	7·7	15	25	8·8	18	29	8·8	18	29
$\frac{3}{4}$	$2\frac{3}{8}$	5·3	4·9	8·5	17	28	9·8	20	32	9·8	20	32
$\frac{25}{32}$	$2\frac{1}{2}$	5·9	5·5	9·6	19	32	11·0	22	36	11·0	22	36
$\frac{27}{32}$	$2\frac{5}{8}$	6·6	6·0	10·5	21	35	12·0	24	40	12·0	24	40
$\frac{7}{8}$	$2\frac{3}{4}$	7·1	6·6	11·5	23	38	13·2	26	44	13·2	26	44
$\frac{29}{32}$	$2\frac{7}{8}$	7·8	7·2	12·6	25	42	14·4	28	48	14·4	28	48
$\frac{15}{16}$	3	8·5	7·8	13·6	27	45	15·6	31	52	15·6	31	52
1	$3\frac{1}{8}$	9·2	8·5	14·8	29	49	17·0	34	56	17·0	34	56
$1\frac{1}{32}$	$3\frac{1}{4}$	9·9	9·1	15·9	31	53	18·2	36	60	18·2	36	60
$1\frac{1}{16}$	$3\frac{3}{8}$	10·7	9·9	17·2	34	57	19·8	39	66	19·8	39	66
$1\frac{1}{8}$	$3\frac{1}{2}$	11·5	10·6	18·5	37	61	21·2	42	70	21·2	42	70
$1\frac{5}{32}$	$3\frac{5}{8}$	12·3	11·4	19·9	39	66	22·8	45	76	22·8	45	76
$1\frac{3}{16}$	$3\frac{3}{4}$	13·2	12·2	21·3	42	71	24·4	48	81	24·4	48	81
$1\frac{7}{32}$	$3\frac{7}{8}$	14·1	13·0	22·7	45	75	26·0	52	86	26·0	52	86
$1\frac{1}{4}$	4	15·0	13·9	24·3	48	81	27·8	55	92	27·8	55	92
$1\frac{5}{16}$	$4\frac{1}{8}$	16·0	14·8	25·9	51	85	29·6	59	98	29·6	59	98
$1\frac{11}{32}$	$4\frac{1}{4}$	17·0	15·7	27·4	54	91	31·4	62	104	31·4	62	104
$1\frac{3}{8}$	$4\frac{3}{8}$	18·0	16·6	29·0	58	96	33·2	66	110	33·2	66	110
$1\frac{7}{16}$	$4\frac{1}{2}$	19·0	17·6	30·8	61	102	35·2	70	117	35·2	70	117
$1\frac{1}{2}$	$4\frac{3}{4}$	21·2	19·6	34·3	68	114	39·2	78	130	39·2	78	130
$1\frac{17}{32}$	$4\frac{7}{8}$	22·0	20·6	36·0	72	126	41·2	82	137	41·2	82	137
$1\frac{19}{32}$	5	23·5	21·7	37·9	75	126	43·4	86	144	43·4	86	144
$1\frac{11}{16}$	$5\frac{1}{4}$	26·0	24·0	42·0	84	140	48·0	96	160	48·0	96	160
$1\frac{3}{4}$	$5\frac{1}{2}$	28·5	26·3	45·5	91	151	52·6	105	175	52·6	105	175
$1\frac{13}{16}$	$5\frac{3}{4}$	31·1	28·7	50·2	100	167	57·4	114	191	57·4	114	191
$1\frac{29}{32}$	6	34·0	31·3	54·7	109	182	62·6	125	208	62·6	125	208

AND STRENGTH (Dixon & Corbitt).

Crucible Steel.			Patent Steel.			Plough Steel.			Extra Plough Steel.		
Breaking Strain.	Working Load.		Breaking Strain.	Working Load.		Breaking Strain.	Working Load.		Breaking Strain.	Working Load.	
	Pit.	Incline.		Pit.	Incline.		Pit.	Incline.		Pit.	Incline.
Tons.	Cwts.	Cwts.	Tons.	Cwts.	Cwts.	Tons.	Cwts.	Cwts.	Tons.	Cwts.	Cwts.
2·7	5	9	3·4	6	11	4·2	8	14	4·9	10	16
3·2	6	10	4·0	8	13	4·9	10	16	5·8	12	19
4·0	8	13	5·0	10	16	6·1	12	20	7·2	14	24
4·7	9	15	5·9	12	20	7·2	14	24	8·5	17	28
5·7	11	18	7·2	14	24	8·7	17	29	10·3	21	34
6·5	13	21	8·0	16	26	9·9	20	33	11·7	24	39
7·5	15	25	9·4	19	31	11·4	23	37	13·5	27	45
8·7	17	29	10·9	22	36	13·3	26	44	15·7	31	52
10·0	20	33	12·6	25	42	15·3	30	50	18·0	36	60
11·0	22	36	13·8	28	46	16·8	33	55	19·8	40	66
12·2	24	40	15·3	31	51	18·7	37	62	22·0	44	73
13·7	27	45	17·2	35	57	21·0	42	70	24·7	49	82
15·0	30	50	19·9	39	66	22·9	46	76	27·0	54	90
16·5	33	55	20·8	43	69	25·1	50	84	29·7	59	99
18·0	36	60	22·6	45	75	27·5	55	91	32·4	64	108
19·5	39	65	24·5	49	81	29·8	59	99	35·1	70	117
21·2	42	70	26·7	53	89	32·5	65	108	38·2	76	127
22·7	45	75	28·6	57	95	34·8	69	116	40·0	82	136
24·7	49	82	31·1	62	103	37·8	75	126	44·5	89	148
26·5	53	88	33·3	67	111	40·5	80	135	47·7	95	159
28·5	57	94	35·9	72	119	43·6	87	145	51·3	102	171
30·5	61	101	38·4	77	128	46·6	93	155	54·0	108	180
32·5	65	108	40·9	82	136	49·7	99	165	58·5	117	195
34·7	69	115	43·7	87	145	53·1	106	177	62·5	125	208
37·0	74	123	46·6	93	155	56·6	113	188	66·6	133	222
39·2	78	130	49·4	99	164	60·0	120	200	70·6	141	235
41·5	83	138	52·2	105	174	63·4	127	211	74·7	149	249
44·0	88	146	55·4	111	184	67·3	134	224	79·2	158	264
49·0	98	163	61·7	123	205	74·9	150	249	88·2	176	294
51·5	103	171	64·8	130	216	78·8	157	262	92·7	185	309
54·2	108	180	68·3	137	227	83·0	166	276	97·6	195	325
60·0	120	200	75·6	151	252	91·8	183	306	108·0	216	360
65·7	131	219	82·8	175	275	100·5	201	335	118·3	238	394
71·7	143	239	90·3	180	301	109·7	219	365	129·1	258	430
78·2	156	260	98·5	197	328	119·7	239	399	140·8	281	469

The next higher working load for Extra Plough Steel Ropes on inclines, in Table 207, is 60 cwts., for which a 2⅛-inch rope is required.

The subjoined table shows the inclination of inclined ways, in inches per yard, and the length for a rise of 1, corresponding to a given number of degrees of inclination; together with the resistance of gravity for each incline.

TABLE 208.—INCLINATION AND RESISTANCE OF INCLINED WAYS.

(Dixon & Corbitt, &c.)

Inclination.	Inclination in Inches per Yard.	Inclination.	Resistance of Gravity due to Incline.	Inclination.	Inclination in Inches per Yard.	Inclination.	Resistance of Gravity due to Incline.
Degs.	Inches.	1 in	Pounds per Ton.	Degs.	Inches	1 in	Pounds per Ton.
1	0·63	57·29	39·08	19	12·39	2·90	729·27
2	1·26	28·63	78·18	20	13·10	2·74	766·12
3	1·88	19·09	117·24	21	13·82	2·60	802·74
4	2·51	14·29	156·26	22	14·54	2·47	839·12
5	3·15	11·42	195·24	23	15·27	2·35	875·23
6	3·78	9·51	234·14	24	16·02	2·24	911·09
7	4·42	8·14	272·98	25	16·78	2·14	946·66
8	5·06	7·11	311·74	26	17·56	2·05	981·94
9	5·70	6·31	350·40	27	18·34	1·96	1016·93
10	6·34	5·67	388·97	28	19·14	1·88	1051·61
11	6·99	5·14	427·41	29	19·95	1·80	1085·97
12	7·65	4·70	465·71	30	20·78	1·73	1120·0
13	8·31	4·33	503·88	31	21·62	1·66	1153·68
14	8·97	4·01	541·90	32	22·49	1·60	1187·02
15	9·64	3·73	579·75	33	23·37	1·54	1219·99
16	10·32	3·48	617·43	34	24·28	1·48	1252·58
17	11·0	3·27	654·90	35	25·20	1·42	1284·81
18	11·69	3·07	692·20				

TABLE 209.—FLAT WIRE ROPES: STRENGTH AND WEIGHT.

(Dixon & Corbitt.)

Sizes.		Weights per Fathom.	Charcoal Iron.		Bessemer or Ingot Iron.		Crucible Steel.		Patent Steel.		Plough Steel.	
			Breaking Strain.	Working Load.	Breaking Strain.	Working Load.	Breaking Strain.	Working Load.	Breaking Strain.	Working Load.	Breaking Strain.	Working Load.
Ins.	Ins.	Lbs.	Tons.	Cwts.	Tons.	Cwts.	Tons.	Cwts.	Tons.	Cwts.	Tons.	Cwts.
$2\frac{1}{8} \times$	$\frac{7}{16}$	9	10	20	14	28	19	38	23	46	36	72
$2\frac{3}{8} \times$	$\frac{7}{16}$	10	12	24	16	32	22	44	27	54	42	84
$2\frac{1}{2} \times$	$\frac{1}{2}$	12	14	28	19	38	25	50	32	64	49	98
$2\frac{3}{4} \times$	$\frac{1}{2}$	14	16	32	22	44	29	58	36	72	56	112
$3 \times$	$\frac{9}{16}$	16	18	36	25	50	34	68	42	84	65	130
$3\frac{1}{4} \times$	$\frac{9}{16}$	18	21	42	29	58	38	76	48	96	74	148
$3\frac{1}{2} \times$	$\frac{5}{8}$	20	23	46	32	64	43	86	54	108	83	166
$3\frac{3}{4} \times$	$\frac{5}{8}$	22	26	52	36	72	49	98	61	122	93	186
$4 \times$	$\frac{11}{16}$	25	29	58	40	80	54	108	67	134	102	204
$4\frac{1}{4} \times$	$\frac{11}{16}$	28	32	64	44	88	58	116	73	146	115	230
$4\frac{1}{2} \times$	$\frac{3}{4}$	30	35	70	48	96	64	128	81	162	124	248
$4\frac{5}{8} \times$	$\frac{3}{4}$	32	37	74	52	104	70	140	88	176	135	270
$4\frac{3}{4} \times$	$\frac{13}{16}$	34	40	80	57	114	76	152	95	190	146	292
$5 \times$	$\frac{7}{8}$	36	44	88	62	124	83	166	104	208	160	320
$5\frac{1}{8} \times$	$\frac{7}{8}$	38	48	96	67	134	89	178	112	224	172	344
$5\frac{1}{4} \times$	$\frac{15}{16}$	40	52	104	72	144	96	192	120	240	184	368
$5\frac{1}{2} \times$	1	42	56	112	78	156	104	208	130	260	200	400
$5\frac{3}{4} \times$	$1\frac{1}{16}$	45	60	120	83	166	111	222	138	276	213	426
$6 \times$	$1\frac{1}{8}$	48	64	128	90	180	120	240	150	300	228	456
$3\frac{1}{4} \times$	$\frac{7}{16}$	13	15	30	22	44	27	54	36	72	54	108
$3\frac{1}{2} \times$	$\frac{1}{2}$	16	18	36	26	52	32	64	43	86	64	128
$3\frac{3}{4} \times$	$\frac{1}{2}$	18	20	40	30	60	37	74	48	96	73	146
$4 \times$	$\frac{9}{16}$	21	24	48	34	64	43	86	56	112	85	170
$4\frac{3}{8} \times$	$\frac{9}{16}$	24	27	54	38	76	49	98	64	128	97	194
$4\frac{5}{8} \times$	$\frac{5}{8}$	27	30	60	43	86	55	110	72	144	108	216
$5 \times$	$\frac{5}{8}$	29	34	68	48	96	63	126	81	162	123	246
$5\frac{1}{4} \times$	$\frac{11}{16}$	32	38	76	53	106	70	140	89	178	135	270
$5\frac{1}{2} \times$	$\frac{11}{16}$	36	41	82	58	116	76	152	97	194	150	300
$5\frac{3}{4} \times$	$\frac{3}{4}$	39	46	92	65	130	84	168	108	216	162	324
$6 \times$	$\frac{3}{4}$	42	50	100	70	140	92	184	119	238	175	350
$6\frac{1}{4} \times$	$\frac{7}{8}$	44	54	108	76	162	99	199	126	252	187	374
$6\frac{1}{2} \times$	$\frac{7}{8}$	47	59	118	83	166	109	218	139	278	208	416
$6\frac{3}{4} \times$	$\frac{15}{16}$	50	63	126	89	178	117	234	149	298	224	448
$7 \times$	1	54	68	136	96	192	126	232	160	320	240	480

TABLE 210.—WIRE CORDS FOR CLOCKS, SASH-LINES, &c. : STRENGTH.

(Dixon & Corbitt.)

No.	Diameter.	Copper.		Phosphor Bronze.		Iron.		Steel.		Patent Steel (Crucible or Open Hearth).	
		Breaking Stress.	Working Load.	Breaking Stress.	Working Load.	Breaking Stress.	Working Load.	Breaking Stress.	Working Load.	Breaking Stress.	Working Load.
	Inch.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
4	·108	181	45	363	90	318	79	493	123	697	174
3½	·117	213	53	428	107	374	93	576	144	817	204
3	·126	248	62	496	124	435	108	671	167	949	237
2¾	·135	286	71	572	143	500	125	778	194	1127	281
2½	·144	324	81	648	162	565	141	875	219	1240	310
2	·153	367	91	734	183	640	160	1005	251	1410	352
1⅞	·171	459	114	918	229	802	200	1248	312	1750	437
1¾	·189	560	140	1121	280	981	245	1539	384	2123	530
1½	·207	671	167	1342	335	1173	293	1815	454	2560	640
1⅜	·225	790	197	1580	395	1382	345	2129	532	2974	743
1¼	·252	992	248	1984	496	1735	434	2673	668	3790	947
1⅛	·288	1294	323	2588	647	2264	566	3500	875	5606	1400
1	·324	1651	410	3283	820	2865	716	4439	1109	6286	1500

Note.—Cords made of six strands of six wires each.

TABLE 211.—SUNDRY WIRE CORDS AND ROPES.

(Dixon & Corbitt.)

GALVANIZED SIGNAL AND FENCING STRAND.

7 Wires. No. .	00	0	1	2	3	4	5	6	7	8	9	10
Diameter. Inch .	·345	·318	·294	·267	·255	·240	·213	·198	·186	·171	·147	·120
Weight per 100 yards. Lbs. .	73	62½	53	44	40	35½	27¾	24¼	21½	18	13¼	9

CAGE GUIDE ROPES.

Inches circumference . .	2¼	2½	2¾	3	3¼	3½	3¾	4	4¼	4½	4¾	5
Weight per fathom. Lbs. .	6¾	8¼	10	11¾	13¾	16	18¼	21	23½	26½	29½	32½

ELECTRO-GILT AND SILVER PICTURE CORDS.

Reference No.	1	2	3	4	5	6
Breaking strain in lbs. . .	48	90	120	200	400	600
Working load	12	22	30	50	100	150

TABLE 212.—ROUND HEMP ROPES: WEIGHT AND STRENGTH.

(Dixon & Corbitt, &c.)

Sizes.		Tarred Russian.			White Manilla.		
Diameter.	Circumference.	Weight per Fathom.	Breaking Strain.	Working Load.	Weight per Fathom.	Breaking Strain.	Working Load.
Inches.	Inches.	Lbs.	Tons.	Cwts.	Lbs.	Tons.	Cwts.
$\frac{5}{8}$	2	1·0	1·0	4	·7	1·2	5
$\frac{23}{32}$	$2\frac{1}{4}$	1·2	1·2	5	·9	1·5	6
$\frac{25}{32}$	$2\frac{1}{2}$	1·5	1·5	6	1·2	2·1	8
$\frac{7}{8}$	$2\frac{3}{4}$	1·8	1·8	8	1·3	2·3	9
$\frac{15}{16}$	3	2·2	2·2	9	1·6	2·8	11
$1\frac{1}{32}$	$3\frac{1}{4}$	2·5	2·5	10	1·9	3·3	13
$1\frac{1}{8}$	$3\frac{1}{2}$	3·0	3·0	12	2·2	3·8	15
$1\frac{3}{16}$	$3\frac{3}{4}$	3·5	3·5	14	2·6	4·5	18
$1\frac{1}{4}$	4	4·0	4·0	16	2·9	5·0	20
$1\frac{11}{32}$	$4\frac{1}{4}$	4·5	4·5	18	3·3	5·7	23
$1\frac{2}{16}$	$4\frac{1}{2}$	5·0	5·0	20	3·7	6·4	25
$1\frac{19}{32}$	5	6·2	6·2	25	4·5	7·8	31
$1\frac{3}{4}$	$5\frac{1}{2}$	7·4	7·4	29	5·5	9·6	38
$1\frac{29}{32}$	6	8·8	8·8	35	6·5	11·3	45
$2\frac{1}{16}$	$6\frac{1}{2}$	10·4	10·4	41	7·6	13·3	53
$2\frac{1}{4}$	7	12·0	12·0	48	8·9	15·5	62
$2\frac{3}{8}$	$7\frac{1}{2}$	13·8	13·8	55	10·2	17·8	71
$2\frac{17}{32}$	8	15·7	15·7	60	11·6	20·3	81
$2\frac{3}{4}$	$8\frac{1}{2}$	17·7	17·7	68	13·0	22·7	91
$2\frac{27}{32}$	9	19·8	19·8	76	14·6	25·5	102
3	$9\frac{1}{2}$	22·1	22·1	88	16·3	28·5	114
$3\frac{3}{16}$	10	24·4	24·4	99	18·0	31·5	126
$3\frac{3}{8}$	$10\frac{1}{2}$	27·0	27·0	108	19·9	34·8	139
$3\frac{1}{2}$	11	29·6	29·6	116	21·8	38·1	152
$3\frac{5}{8}$	$11\frac{1}{2}$	32·4	32·4	131	23·8	41·6	166
$3\frac{13}{16}$	12	35·2	35·2	141	26·0	45·5	182
4	$12\frac{1}{2}$	38·2	38·2	153	28·2	49·3	197
$4\frac{5}{32}$	13	41·4	41·4	167	30·5	53·9	215
$4\frac{3}{16}$	$13\frac{1}{2}$	44·6	44·6	176	32·8	57·4	229
$4\frac{7}{16}$	14	48·0	48·0	192	35·3	61·7	247
$4\frac{5}{8}$	$14\frac{1}{2}$	51·5	51·5	204	37·8	66·1	264
$4\frac{3}{4}$	15	55·0	55·0	220	40·5	70·0	280
5	16	62·6	62·6	248	46·1	80·6	322
$5\frac{13}{32}$	17	70·7	70·7	280	52·0	91·0	364
$5\frac{3}{4}$	18	79·2	79·2	317	58·3	102	408

TABLE 213.—FLAT HEMP ROPES: WEIGHT AND STRENGTH.

(Dixon & Corbitt, &c.)

Sizes.	Tarred Russian.			Combined Russian and Manilla.		
	Weight per Fathom.	Breaking Stress.	Working Load.	Weight per Fathom.	Breaking Stress.	Working Load.
Inches.	Pounds.	Tons.	Cwts.	Pounds.	Tons.	Cwts.
FOUR ROPES.						
$3\frac{1}{2} \times 1$	10	10	20	$9\frac{1}{2}$	11	22
$4 \times 1\frac{1}{16}$	$13\frac{1}{2}$	$13\frac{1}{2}$	27	$12\frac{1}{2}$	15	30
$4\frac{1}{2} \times 1\frac{3}{16}$	17	17	34	16	19	38
$5 \times 1\frac{3}{8}$	21	21	42	$19\frac{1}{2}$	23	46
$5\frac{1}{2} \times 1\frac{1}{2}$	25	25	50	$23\frac{1}{2}$	28	56
$6 \times 1\frac{5}{8}$	30	30	60	28	33	66
$6\frac{1}{2} \times 1\frac{3}{4}$	34	34	68	32	38	76
$7 \times 1\frac{7}{8}$	38	38	76	36	43	86
$7\frac{1}{2} \times 2$	43	43	86	40	48	96
SIX ROPES.						
$4 \times \frac{13}{16}$	10	10	20	$9\frac{1}{2}$	11	22
$4\frac{1}{2} \times \frac{15}{16}$	13	13	26	12	14	28
5×1	16	16	32	$14\frac{1}{2}$	17	34
$5\frac{1}{8} \times 1\frac{3}{8}$	19	19	38	16	20	40
$6 \times 1\frac{1}{4}$	22	22	24	20	24	28
$6\frac{1}{2} \times 1\frac{3}{8}$	25	25	50	$22\frac{1}{2}$	27	54
$7 \times 1\frac{1}{2}$	28	28	56	25	30	60
$7\frac{1}{2} \times 1\frac{1}{2}$	32	32	64	29	34	68
$8 \times 1\frac{5}{8}$	36	36	72	33	39	78

TABLE 214.—HEMP ROPES AND WIRE ROPES: SIZE AND WEIGHT FOR EQUAL STRENGTHS.

(J. Shaw.)

I. ROUND ROPES.

Hemp.		Crucible Cast Steel.		Charcoal Wire.		Strength.	
Circumference.	Weight per Fathom (approximate).	Circumference.	Weight per Fathom (approximate).	Circumference.	Weight per Fathom (approximate).	Breaking Stress.	Working Load (approximate).
Inches.	Pounds.	Inches.	Pounds.	Inches.	Pounds.	Tons.	Cwts.
3½	3	1¼	1½	1½	2	2¾	9
4	4	1⅜	1¾	1¾	2¾	4	15
4½	5	1½	2	2	3¼	6	20
5	6½	1¾	2¾	2¼	4½	7½	24
5½	7½	1⅞	3	2½	5½	9½	30
6	8½	2	3¼	2¾	6½	11½	36
6½	10	2¼	4½	3	7¾	14	45
7	12	2½	5½	3¼	8½	16	52
7½	14	2⅝	6	3½	10½	19	62
8	16	2¾	6½	3¾	12½	22	74
8½	18	3	7¾	4	14	25	80
9	20	3¼	9¼	4¼	16	28	95
9½	23	3½	10¾	4½	18	32	105
10	26	3¾	12½	4¾	20	36	120
10½	29	4	14¼	5	22	40	135
11	31	4⅛	15	5¼	25	45	150
11½	34	4¼	16	5½	28	50	160
12	37	4½	18	5¾	31	55	170
13	41	4¾	20	6	35	60	180

II. FLAT ROPES.

Sizes. Inches.		Sizes. Inches.		Sizes. Inches.			
3½ × 1	12	…	…	2¼ × ½	10	18	40
4 × 1¼	15	…	…	2½ × ½	12	20	45
4½ × 1½	20	…	…	2¾ × ⅝	14	23	51
5 × 1¾	24	2¼ × ½	10	3 × ⅝	16	27	56
5½ × 1¾	27	2½ × ½	12	3¼ × ⅝	18	30	60
6¼ × 1⅞	30	2¾ × ⅝	14	3½ × ⅝	20½	33	68
6½ × 2	33	3 × ⅝	16	3¾ × ¾	22½	36	78
7 × 2	36	3¼ × ⅝	18½	4 × ¾	25	39	90
7¼ × 2⅛	39	3½ × ⅝	21	4¼ × ⅞	28	42	106
8 × 2¼	42	3¾ × ¾	22½	4½ × ⅞	32	45	118

TABLE 215.—STEEL WIRE ROPES: BREAKING STRESS.
(J. Shaw.)

Plough Steel Wire Rope.		Hard Steel Ropes.		Iron Wire Guides, or Conducting Rods.	
Circumference.	Breaking Stress.	Circumference.	Breaking Stress.	Circumference.	Weight per Fathom.
Inches.	Tons.	Inches.	Tons.	Inches.	Pounds.
1½	12	1½	9½	2¾	13
1¾	15½	1¾	11½	3	15
2	18	2	14	3¼	18
2¼	24	2¼	17	3½	21
2½	27	2½	21	3¾	24
2¾	31½	2¾	26	4	28
3	38	3	31		
3¼	46	3¼	37		
3½	53	3½	42		
3¾	59	3¾	50		
4	68	4	55		
4¼	76	4¼	63		
4½	88	4½	71		
5	100	5	90		

Duboul's Experiments on the Strength of Ropes.

M. Duboul tested ropes and cables of white hemp and tarred hemp, Italian, Russian, and French; of long fibre, hand spun, with from fifty to fifty-five twists to the yard; 1½ yards of rope yarn sufficing to make one yard of cable. A selection of results is given in Table 216.

Flat tarred ropes were proved to a mean strength of from 3·43 tons to 3·75 tons per square inch, rupture taking place at the points of attachment. The extension rarely exceeded from 5 to 6 per cent.

The average ultimate tensile strength of rope was as follows:—

	Tons.		Tons.	
White hemp	4·76	to	5·08	per square inch.
Tarred hemp	3·54	,,	3·81	,, ,, ,,
White Manilla	4·44	,,	4·76	,, ,, ,,
White aloes	2·54	,,	3·17	,, ,, ,,
Flat ropes of tarred hemp, or Tarred Manilla	3·54	,,	3·81	,, ,, ,,
Esparto and cocoa fibres . . .	1·00	,,	1·25	,, ,, ,,

M. Duboul deduced from results of practice that round ropes and cables may be worked at a stress equal to one-third of the ultimate strength; and flat ropes at one-fourth. In ordinary practice, the proportion is often not more than from one-sixth to one-eighth.

TABLE 216.—RESULTS OF TESTS OF ROUND ROPES.

(M. Duboul.)

		White Hemp.		Tarred Hemp.		White Manilla.		White Aloes.	
Circumference before rupture . .	Inches	4·33	4·33	4·25	4·25	3·94	3·94	4·33	4·33
,, after ,, . .	,,	3·86	3·74	3·70	3·74	3·27	3·39	3·54	3·66
Length tested	Feet	32·8	32·8	32·8	32·8	32·8	32·8	32·8	32·8
,, measured for testing extension	,,	13·1	13·1	13·1	13·1	13·1	13·1	13·1	13·1
Extension	Inches	27·2	28·3	25·6	26·4	23·2	22·8	26·0	26·8
Section of the four strands .	Square Inch	·819	·819	·819	·819	·819	·819	·819	·819
Section of the piece . . .	,,	1·490	1·490	1·481	1·481	1·246	1·246	1·491	1·491
Resistance	Tons	7·94	7·43	5·22	5·64	5·44	5·96	3·99	4·45
,, of the four strands per square inch . . .	,,	9·78	9·02	6·35	6·86	6·60	7·24	4·83	5·40
,, of the piece per square inch	,,	5·27	4·95	3·49	3·87	4·32	4·76	2·67	2·98
Weight of the whole piece tested .	Pounds	17·4	17·6	18·7	19·6	15·0	15·2	15·0	15·4

M. Duboul estimates that ropes and cables of galvanized charcoal-iron wire unannealed, have two-tenths of the diameter of hemp cables of equal strength; or three-tenths for annealed wire.

	Ultimate Strength per Square Inch, Section of Metal.	Extension.	Elasticity.
Rope of unannealed wire	25·4 to 31·7 tons	7 to 9 °/₀	1 to 2 °/₀
„ annealed „	22·2 to 25·4 „	12 to 15 „	3 to 4 „

The galvanized wire tested by itself, yields 10 per cent. more resistance to rupture than in the form of rope.

Wire-ropes for mining service, of the first quality, have an ultimate strength of from 40 to 45 tons per square inch of metal section.

Cast-steel wire ropes stretch from 4 to 6 per cent. before rupture, with an elastic limit of from 2 to 3½ per cent. They bear three-fourths of the breaking stress before exhibiting any sign of failure.

TABLE 217.—STEEL WIRE ROPE, FOR STANDING RIGGING. (Admiralty.)

Size of Rope (Girth).	Number of Strands.	Wires in one Strand.	Thickness of Wires.	Weight per Fathom.	Length of one Coil.	Breaking Stress (Minimum).
Inches.	Strands.	Wires.	I. W. G.	Pounds.	Fathoms.	Tons.
8	6	19	6	62	100	160
7½	6	19	7	53	100	141
7	6	19	8	46	100	123
6½	6	19	6	40	100	106
6	6	19	10	34	100	90
5½	6	19	10	28	100	76
5	6	19	12	23	100	63
4½	6	19	12	19	150	51
4	6	19	14	15½	150	40
3½	6	7	10	11½	150	32
3¼	6	7	11	10	150	27
3	6	7	12	8	200	24
2¾	6	7	13	7	200	19
2½	6	7	13	6	200	16
2¼	6	7	14	5	200	13
2	6	7	15	4	200	10
1¾	6	7	16	3	200	8
1½	6	7	18	2	200	6
1¼	6	7	18	1½	200	3¾
1	6	7	20	1	200	2½

TABLE 218.—STEEL WIRE ROPES, FOR HAWSERS AND RUNNING RIGGING.

(Admiralty.)

Size of Rope (Girth).	Number of Strands.	Wires in one Strand.	Thickness of Wires.	Weight per Fathom.	Length of one Coil.	Breaking Stress (Minimum).
Inches.	Strands.	Wires.	I. W. G.	Pounds.	Fathoms.	Tons.
8	6	30	9	...	150	...
7	6	30	11	...	150	...
6½	6	30	12	35	150	98
6	6	30	12	31	150	84
5½	6	25	12	28	150	71
5	6	25	13	23	150	59
4½	6	12	12	15	150	39
4	6	12	13	12	240	31
3½	6	12	14	9	360	24
3¼	6	12	15	8	360	20
3	6	12	16	7	360	17
2¾	6	12	17	5½	360	14½
2½	6	12	17	4½	360	11¾
2¼	6	12	18	3¾	300	9
2	6	12	19	2¾	300	7
1¾	6	12	20	2	300	5½
1½	6	12	21	1¾	300	4
1¼	6	12	22	1¼	300	2⅞
1	6	12	24	¾	300	1¾

Resistance of Ropes to Bending Stress.

The resistance of ropes to bending stress in passing over a pulley or a barrel is expressed by the following formulas, the equivalents in English measures of Longraire's formulas :—

Hemp Ropes, either White or Tarred.

$$S = \cdot 0328\, T \frac{w}{D} \quad . \quad . \quad . \quad . \quad (125)$$

Iron Wire Ropes (Hemp Core).

$$S = (3\cdot 61 + \cdot 00262\, T) \frac{w}{D} \quad . \quad . \quad . \quad . \quad (126)$$

Steel Wire Ropes (Hemp Core).

$$S = (6{\cdot}314 + {\cdot}00262\ T)\ \frac{w}{D} \qquad . \qquad . \ (127)$$

Steel Wire Ropes, rusted.

$$S = (5{\cdot}412 + {\cdot}00262\ T)\ \frac{w}{D} \qquad . \qquad . \quad . \ (128)$$

Steel Wire Ropes, Lubricated in Oil Bath.

$$S = (3{\cdot}428 + {\cdot}00172\ T)\ \frac{w}{D} \qquad . \qquad . \ (129)$$

S = resistance to bending stress; or the total tensile stress or pull minus the resisting stress in the rope, in the advancing limb of the rope.
T = resisting stress on the rope, in the advancing limb of the rope.
w = weight of rope per fathom, in pounds.
D = diameter of pulley or barrel, in feet.

The foregoing formulas apply to ropes which are new or nearly new; and for wire ropes of wire 3 millimetres, or about $\frac{1}{8}$ inch thick. The resistance may be reduced ultimately by wear by 20 per cent. for iron ropes, and 33 per cent. for steel ropes. The experiments were made with wire ropes of from 6 lbs. to 13 lbs. per fathom, or from ·83 inch to 1·30 inch in diameter.

CHAINS AND CHAIN-CABLES.

Cables for use in the naval and merchant service are made of round iron, in lengths of 15 fathoms, with stud-links. For standing rigging and crane chain, short or unstudded links are employed.

Chains are made of puddled iron, bars of which have, or ought to have, an ultimate tensile strength of 23 tons per square inch, stretching from 20 to 25 per cent. in a length of 10 inches; with a contraction of sectional area of from 45 to 50 per cent.

The links of chain-cables and short links generally are geometrically similar for all sizes, according to the following proportions, which are those of the links after having been submitted to the proof stress: the length of the common stud-link being 6 diameters, and the width about $3\frac{1}{2}$ diameters, whilst the length and width of the short-link are respectively about 5 diameters and $3\frac{1}{2}$ diameters.

		Stud-Link.	Short-Link.
	Diameter of iron	1	1
Common Links	Length of link outside	6	4·9
	Width of link outside	3·6	3·5
	Radius of each end inside	·58	·60
	Length of stud at crown	1·6	—
	Width in parts of length	60 per cent.	71 per cent.
Enlarged Links	Diameter of iron	1·1	1·1
	Length of link outside	6·5	5·7
	Width of link outside	4·0	3·8
	Radius of each end inside	·64	·65
End Links	Diameter of iron	1·2	1·2
	Length of link outside	6·5	6·6
	Width of link outside	4·0	4·1

The length of one link varies as the size or diameter, whilst the weight is as the cube of the diameter. The weight per unit of length,—say, one fathom,—varies, therefore, as the square of the diameter, and is expressed by the following formulæ, in which d is the size or diameter in inches, and W is the weight per fathom in pounds :—

(Stud-link chains) . . $W = 53{\cdot}76\,d^2$ . . (130)

(Short-link or crane chain) . $W = 55\,d^2$ . . . (131)

The proof tensile strength also varies as the square of the diameter, and therefore it varies as the weight.

	Stud-Link.	Short-Link.	
The actual ultimate strength of good ordinary cable, in tons . . .	$=29d^2$ to $26{\cdot}7d^2$	$27{\cdot}3d^2$ to $25{\cdot}1d^2$	(132)
The statutory ultimate strength in tons . . .	$=27d^2$ to $25{\cdot}2d^2$	$24d^2$	(133)
The statutory proof strength in tons . .	$=18d^2$	$12d^2$	(134)
The safe-working stress (half the proof strength) .	$=9d^2$	$6d^2$	(135)

It is here shown that whilst the actual ultimate strength (132) of short-links is little less than that of stud-links, the proof stress and the safe-working stress, (134) and (135), for the short-links, are only two-thirds of those for the stud-links, by reason of the lower elastic limit of the short links.

The Tables 219 and 220, from which the foregoing formulæ have been deduced, give the dimensions, weight, and strength of stud-link and short-link chain-cables. In Table 220, for short-links, there are no statutory tests for cables above $1\frac{5}{8}$ inches in diameter; but the appropriate stresses, with actual strengths for the larger sizes, calculated and supplied by Mr. T. Traill (in "*Chain-Cables and Chains*") are added in the table. In the second last column are given the safe-working strengths of cables, the factor of strength averaging for stud-links a little over 3; and for short-links about $4\frac{1}{4}$.

The safe-working load in tons is approximately expressed by the following formulæ :—

$$\text{Short-link chain} \quad . \quad . \quad . \quad \frac{D^2}{10} \quad . \quad . \quad . \quad (136)$$

$$\text{Stud-link chain} . \quad . \quad . \quad . \quad \frac{D^2}{7} \quad . \quad . \quad . \quad (137)$$

in which D is the diameter of the iron in eighths of an inch. The values thus obtained are about 7 per cent. too high for the short-link chain, and about 1 per cent. too high for the stud-link chain.

The Admiralty have special proportions for iron chain rigging and crane work, for which the sizes and weights are given in Table 222. The Admiralty chain moorings are noted in Table 221, in which the sizes, weights, and proof stresses are given. They are of unstudded or open links, and these are shaped differently from the ordinary short-link, being made thicker at the ends, the wearing parts. Mooring chains are in consequence heavier than short-link chains of the same sizes.

The India Office prescribe for all services, except Marine, short-link chains, of which the common links are not to exceed $4\frac{1}{2}$ diameters in length, and $3\frac{1}{4}$ diameters in width. The weight and conditions of test are given in Table 223.

In the Trinity House contracts, it is specified that mooring chains, chain cables, crane and rigging chains, and appurtenances, except the stay-pins and steel pins, are to be of fibrous iron, to have a tensile stress of not less than 23 tons per square inch, with a contraction of sectional area at the fracture of not less than 40 per cent. of the original area. The cast iron of which the stay-pins are made is to have a compressive stress of not less than 52 tons per square inch of

TABLE 219.—STUD-LINK CHAIN-CABLES: DIMENSIONS, WEIGHT, AND STRENGTH.

Diameter of Iron.	Length of One Link, Outside.	Width of One Link, Outside.	Radius of End of Link, Inside.	Length of Stud at Crown.	Weight of		Statutory Proof Tensile Stress, for each 15 Fathoms separately.	Statutory Ultimate Strength or Breaking Stress, on Three Links in each 15 Fathoms.	Actual Breaking Stress.		Safe-Working Stress (Half the Proof Stress).	Ultimate or Breaking Stress per Square Inch of Good Ordinary Cable.
					100 Fathoms.	One Fathom (Six Feet).			Good Ordinary Cable.	High Breaking Stress.		
Inches.	Inches.	Inches.	Inches.	Inches.	Cwts.	Pounds.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
$\frac{7}{16}$	$2\frac{5}{8}$	$1\frac{19}{32}$	$\frac{1}{4}$	$\frac{23}{32}$	9·2	11·3	3·4	5·1	5·4	$5\frac{3}{4}$	1·7	18·0
$\frac{1}{2}$	3	$1\frac{13}{16}$	$\frac{9}{32}$	$\frac{13}{16}$	12	13·4	4·5	$6\frac{3}{4}$	$7\frac{1}{8}$	7·6	$2\frac{1}{4}$	18·1
$\frac{9}{16}$	$3\frac{3}{8}$	$2\frac{1}{32}$	$\frac{11}{32}$	$\frac{29}{32}$	15·2	17·2	$5\frac{5}{8}$	8·4	9	$9\frac{5}{8}$	2·81	18·1
$\frac{5}{8}$	$3\frac{3}{4}$	$2\frac{1}{4}$	$\frac{3}{8}$	1	18·75	21	7	10·5	11·2	11·9	$3\frac{1}{2}$	18·2
$\frac{11}{16}$	$4\frac{1}{8}$	$2\frac{15}{32}$	$\frac{13}{32}$	$1\frac{3}{32}$	22·7	25·4	8·5	$12\frac{3}{4}$	13·6	14·5	$4\frac{1}{4}$	18·3
$\frac{3}{4}$	$4\frac{1}{2}$	$2\frac{11}{32}$	$\frac{7}{16}$	$1\frac{3}{16}$	27	30·2	$10\frac{1}{8}$	$15\frac{1}{8}$	16·2	17·3	$5\frac{1}{16}$	18·3
$\frac{13}{16}$	$4\frac{7}{8}$	$2\frac{15}{16}$	$\frac{15}{32}$	$1\frac{5}{16}$	31·7	35·5	$11\frac{7}{8}$	17·8	19	$20\frac{3}{8}$	5·94	18·3
$\frac{7}{8}$	$5\frac{1}{4}$	$3\frac{5}{32}$	$\frac{17}{32}$	$1\frac{13}{32}$	36·75	41·2	$13\frac{3}{4}$	$20\frac{5}{8}$	$22\frac{1}{8}$	$23\frac{5}{8}$	$6\frac{7}{8}$	18·3
$\frac{15}{16}$	$5\frac{5}{8}$	$3\frac{3}{8}$	$\frac{9}{16}$	$1\frac{1}{2}$	42·2	47·2	15·8	23·7	25·4	$27\frac{1}{4}$	7·9	18·4
1	6	$3\frac{19}{32}$	$\frac{19}{32}$	$1\frac{19}{32}$	48	53·8	18	27	29	31·1	9	18·5
$1\frac{1}{16}$	$6\frac{3}{8}$	$3\frac{27}{32}$	$\frac{5}{8}$	$1\frac{23}{32}$	54·2	60·7	20·3	30·4	$32\frac{5}{8}$	34·9	10·15	18·4
$1\frac{1}{8}$	$6\frac{3}{4}$	$4\frac{1}{16}$	$\frac{21}{32}$	$1\frac{13}{16}$	60·75	69	$22\frac{3}{4}$	$34\frac{1}{8}$	36·5	39	$11\frac{3}{8}$	18·3
$1\frac{3}{16}$	$7\frac{1}{8}$	$4\frac{9}{32}$	$\frac{11}{16}$	$1\frac{29}{32}$	67·7	75·8	$25\frac{3}{8}$	38	40·5	$43\frac{3}{8}$	12·69	18·3
$1\frac{1}{4}$	$7\frac{1}{2}$	$4\frac{1}{2}$	$\frac{3}{4}$	2	75	84	$28\frac{1}{8}$	$42\frac{1}{8}$	$44\frac{3}{4}$	47·9	$14\frac{1}{16}$	18·2
$1\frac{5}{16}$	$7\frac{7}{8}$	$4\frac{23}{32}$	$\frac{25}{32}$	$2\frac{3}{32}$	82·4	92	31	46·5	$49\frac{1}{8}$	$52\frac{5}{8}$	$15\frac{1}{2}$	18·2
$1\frac{3}{8}$	$8\frac{1}{4}$	$4\frac{15}{16}$	$\frac{13}{16}$	$2\frac{3}{16}$	90·75	101·6	34	51	$53\frac{3}{4}$	57·5	17	18·1

TABLE 219.—STUD-LINK CHAIN-CABLES (*continued*).

Diameter of Iron.	Length of One Link, Outside.	Width of One Link, Outside.	Radius of End of Link, Inside.	Length of Stud at Crown.	Weight of		Statutory Proof Tensile Stress, for each 15 Fathoms separately.	Statutory Ultimate Strength or Breaking Stress, on Three Links in each 15 Fathoms.	Actual Breaking Stress.		Safe-Working Stress (Half the Proof Stress).	Ultimate or Breaking Stress per Square Inch of Good Ordinary Cable.
					100 Fathoms.	One Fathom (Six Feet).			Good Ordinary Cable.	High Breaking Stress.		
Inches.	Inches.	Inches.	Inch.	Inches.	Cwts.	Pounds.	Tons.	Tons.	Tons	Tons.	Tons.	Tons.
$1\frac{7}{16}$	$8\frac{5}{8}$	$5\frac{3}{16}$	$\frac{27}{32}$	$2\frac{5}{16}$	99·5	111	$37\frac{1}{8}$	$55\frac{5}{8}$	$58\frac{5}{8}$	62·7	18·56	18·0
$1\frac{1}{2}$	9	$5\frac{13}{32}$	$\frac{7}{8}$	$2\frac{13}{32}$	108	121	40·5	58·7	63·6	68	$20\frac{1}{4}$	18·0
$1\frac{9}{16}$	$9\frac{3}{8}$	$5\frac{5}{8}$	$\frac{29}{32}$	$2\frac{1}{2}$	116·8	131	43·9	61·4	68·7	73·6	22	17·9
$1\frac{5}{8}$	$9\frac{3}{4}$	$5\frac{27}{32}$	$\frac{15}{16}$	$2\frac{19}{32}$	126·75	142	47·5	66·5	74	79·3	$23\frac{3}{4}$	17·8
$1\frac{11}{16}$	$10\frac{1}{8}$	$6\frac{3}{32}$	1	$2\frac{23}{32}$	138·7	152	$51\frac{1}{4}$	$71\frac{3}{4}$	$79\frac{5}{8}$	85·2	$25\frac{1}{2}$	17·8
$1\frac{3}{4}$	$10\frac{1}{2}$	$6\frac{5}{16}$	$1\frac{1}{32}$	$2\frac{13}{16}$	147	164·6	$55\frac{1}{8}$	$77\frac{1}{8}$	$85\frac{3}{8}$	$91\frac{3}{8}$	$27\frac{1}{2}$	17·7
$1\frac{13}{16}$	$10\frac{7}{8}$	$6\frac{17}{32}$	$1\frac{1}{16}$	$2\frac{29}{32}$	158	176	$59\frac{1}{8}$	$82\frac{3}{4}$	91·2	$97\frac{5}{8}$	$29\frac{1}{2}$	17·7
$1\frac{7}{8}$	$11\frac{1}{4}$	$6\frac{3}{4}$	$1\frac{3}{32}$	3	168·75	189	$63\frac{1}{4}$	88·5	$97\frac{1}{4}$	$104\frac{1}{8}$	$31\frac{5}{8}$	17·6
$1\frac{15}{16}$	$11\frac{5}{8}$	$6\frac{31}{32}$	$1\frac{1}{8}$	$3\frac{3}{32}$	180	201	67·5	94·5	$103\frac{1}{2}$	110·8	$33\frac{3}{4}$	17·6
2	12	$7\frac{3}{16}$	$1\frac{5}{32}$	$3\frac{3}{16}$	192	215	72	100·8	109·9	$117\frac{5}{8}$	36	17·5
$2\frac{1}{16}$	$12\frac{3}{8}$	$7\frac{7}{16}$	$1\frac{7}{32}$	$3\frac{5}{16}$	203	228	76·5	107·1	116·4	124·5	$38\frac{1}{4}$	17·4
$2\frac{1}{8}$	$12\frac{3}{4}$	$7\frac{21}{32}$	$1\frac{1}{4}$	$3\frac{13}{32}$	216·75	242·8	$81\frac{1}{4}$	$113\frac{3}{4}$	$123\frac{1}{8}$	131·9	$40\frac{5}{8}$	17·3
$2\frac{3}{16}$	$13\frac{1}{8}$	$7\frac{7}{8}$	$1\frac{9}{32}$	$3\frac{1}{2}$	229	259	$86\frac{1}{8}$	120·5	130·1	$139\frac{1}{4}$	43	17·3
$2\frac{1}{4}$	$13\frac{1}{2}$	$8\frac{3}{32}$	$1\frac{5}{16}$	$3\frac{19}{32}$	243	276·2	$91\frac{1}{8}$	127·5	$137\frac{1}{8}$	$146\frac{3}{4}$	$45\frac{1}{2}$	17·2
$2\frac{5}{16}$	$13\frac{7}{8}$	$8\frac{11}{32}$	$\frac{11}{32}$	$3\frac{23}{32}$	256	289	$96\frac{1}{4}$	$134\frac{3}{4}$	$144\frac{1}{4}$	$154\frac{1}{2}$	$48\frac{1}{8}$	17·2
$2\frac{3}{8}$	$14\frac{1}{4}$	$8\frac{9}{16}$	$1\frac{3}{8}$	$3\frac{13}{16}$	270·75	303·2	101·5	142·1	$151\frac{5}{8}$	162·4	$50\frac{3}{4}$	17·1
$2\frac{7}{16}$	$14\frac{5}{8}$	$8\frac{25}{32}$	$1\frac{13}{32}$	$3\frac{29}{32}$	285	319	106·9	$149\frac{5}{8}$	159·2	170·4	$53\frac{1}{2}$	17·1
$2\frac{1}{2}$	15	9	$1\frac{15}{32}$	4	300	336	112·5	157·5	$166\frac{7}{8}$	$178\frac{5}{8}$	$56\frac{1}{4}$	17·0

TABLE 220.—SHORT-LINK OR UNSTUDDED CHAIN-CABLES: DIMENSIONS, WEIGHT, AND STRENGTH.

Diameter of Iron.	Length of One Link, Outside.	Width of One Link, Outside.	Radius of End of Link, Inside.	Weight of One Fathom (Six Feet).	Statutory Proof Tensile Stress, for each 15 Fathoms separately.	Statutory Breaking Stress, or Ultimate Strength, in Three Links in each 15 Fathoms.	Actual Breaking Stress.		Safe-Working Stress (Half the Proof Stress).	Ultimate Breaking Stress per Sq. Inch of Good Ordinary Cable.
							Good Ordinary Cable.	High Breaking Stress.		
Inches.	Inches.	Inches.	Inch.	Pounds.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
1/4	1 7/32	7/8	5/32	3·44	3/4	1 1/2	1 5/8	1·7	3/8	16·6
5/16	1 17/32	1 3/32	3/16	5 1/2	1 1/8	2 1/4	2·6	2 5/8	9/16	16·8
3/8	1 27/32	1 5/16	7/32	8	1 5/8	3 1/4	3 3/4	3·9	13/16	17·0
7/16	2 1/8	1 17/32	9/32	10 1/2	2 1/4	4 1/2	5 1/8	5·3	1 1/8	17·1
1/2	2 7/16	1 3/4	5/16	13 3/4	3	6	6 3/4	7	1 1/2	17·1
9/16	2 3/4	1 31/32	11/32	17	3 3/4	7 1/2	8 1/2	8·9	1 7/8	17·2
5/8	3 1/16	2 3/16	3/8	22	4 5/8	9 1/4	10 1/2	11	2 5/16	17·2
11/16	3 3/8	2 13/32	13/32	26	5 5/8	11 1/4	12·8	13·4	2 13/16	17·2
3/4	3 11/16	2 5/8	15/32	30	6 3/4	13 1/2	15 1/4	16	3 3/8	17·3
13/16	3 31/32	2 27/32	1/2	36	7·9	15·8	17·9	18·8	4	17·3
7/8	4 9/32	3 1/16	17/32	42	9 1/8	18 1/4	20·8	21 7/8	4 9/16	17·3
15/16	4 19/32	3 9/32	9/16	49	10 1/2	21	23·9	25 1/8	5 1/4	17·4
1	4 29/32	3 1/2	19/32	55	12	24	27·3	28 5/8	6	17·4
1 1/16	5 7/32	3 23/32	21/32	60	13 1/2	27	30·7	32 1/4	6 3/4	17·3
1 1/8	5 1/2	3 15/16	11/16	68	15 1/8	30 1/4	34·3	36	7 1/2	17·2
1 3/16	5 13/16	4 5/32	23/32	76	16·9	33·8	38 1/8	39·9	16 1/2	17·1
1 1/4	6 1/8	4 3/8	3/4	84	18 3/4	37 1/2	42 1/8	44 1/8	9 3/8	17·0

TABLE 220.—SHORT-LINK CHAIN CABLES (*continued*).

Diameter of Iron.	Length of One Link, Outside.	Width of One Link, Outside.	Radius of End of Link, Inside.	Weight of One Fathom (Six Feet).	Statutory Proof Tensile Stress, for each 15 Fathoms separately.	Statutory Breaking Stress, or Ultimate Strength, in Three Links in each 15 Fathoms.	Actual Breaking Stress.		Safe-Working Stress (Half the Proof Stress).	Ultimate Breaking Stress per Sq. Inch of Good Ordinary Cable.
							Good Ordinary Cable.	High Breaking Stress.		
Inches.	Inches.	Inches.	Inches.	Pounds.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
$1\frac{5}{16}$	$6\frac{7}{16}$	$4\frac{19}{32}$	$\frac{25}{32}$	93	$20\frac{5}{8}$	$41\frac{1}{4}$	$46\frac{1}{4}$	$48\frac{1}{2}$	$10\frac{1}{4}$	17·0
$1\frac{3}{8}$	$6\frac{3}{4}$	$4\frac{13}{16}$	$\frac{27}{32}$	102	$22\frac{5}{8}$	$45\frac{1}{4}$	50·6	53	$11\frac{1}{4}$	17·0
$1\frac{7}{16}$	$7\frac{1}{32}$	$5\frac{1}{32}$	$\frac{7}{8}$	111	$24\frac{3}{4}$	$49\frac{1}{2}$	$55\frac{1}{3}$	57·8	$12\frac{3}{8}$	17·0
$1\frac{1}{2}$	$7\frac{11}{32}$	$5\frac{1}{4}$	$\frac{29}{32}$	120	27	54	59·8	62·7	$13\frac{1}{2}$	16·9
$1\frac{9}{16}$	$7\frac{21}{32}$	$5\frac{15}{32}$	$\frac{15}{16}$	131	$29\frac{1}{4}$	$58\frac{1}{2}$	$64\frac{5}{8}$	67·8	$14\frac{5}{8}$	16·9
$1\frac{5}{8}$	$7\frac{31}{32}$	$5\frac{11}{16}$	1	144	$31\frac{5}{8}$	$63\frac{1}{4}$	69·7	73	$15\frac{3}{4}$	16·8
$1\frac{11}{16}$	$8\frac{9}{32}$	$5\frac{20}{32}$	$1\frac{1}{32}$	159	$34\frac{1}{8}$	$68\frac{1}{4}$	74·9	$78\frac{1}{2}$	17	16·8
$1\frac{3}{4}$	$8\frac{11}{32}$	$6\frac{1}{8}$	$1\frac{1}{16}$	168	$36\frac{3}{4}$	$73\frac{1}{2}$	80·3	$84\frac{1}{3}$	$18\frac{3}{8}$	16·8
$1\frac{13}{16}$	$8\frac{7}{8}$	$6\frac{11}{32}$	$1\frac{3}{32}$	181	39·4	78·8	85·8	90	$19\frac{3}{4}$	16·7
$1\frac{7}{8}$	$9\frac{3}{16}$	$6\frac{9}{16}$	$1\frac{1}{8}$	196	$42\frac{1}{3}$	$84\frac{1}{4}$	$91\frac{1}{2}$	95·9	21	16·6
$1\frac{15}{16}$	$9\frac{1}{2}$	$6\frac{25}{32}$	$1\frac{5}{32}$	207	45	90	97·4	102	$22\frac{1}{2}$	16·5
2	$9\frac{13}{16}$	7	$1\frac{7}{32}$	220	48	96	103·4	$108\frac{3}{8}$	24	16·4
$2\frac{1}{16}$	$10\frac{1}{8}$	$7\frac{7}{32}$	$1\frac{1}{4}$	233	51	102	$109\frac{5}{8}$	114·8	$25\frac{1}{2}$	16·4
$2\frac{1}{8}$	$10\frac{13}{32}$	$7\frac{7}{16}$	$1\frac{9}{32}$	248	$54\frac{1}{8}$	$108\frac{1}{4}$	115·9	121·4	27	16·3
$2\frac{3}{16}$	$10\frac{23}{32}$	$7\frac{21}{32}$	$1\frac{5}{16}$	262	57·4	114·8	122·4	128·2	$28\frac{3}{4}$	16·3
$2\frac{1}{4}$	$11\frac{1}{32}$	$7\frac{7}{8}$	$1\frac{11}{32}$	272	$60\frac{3}{4}$	$121\frac{1}{2}$	129	$135\frac{1}{8}$	$30\frac{3}{8}$	16·2
$2\frac{5}{16}$	$11\frac{11}{32}$	$8\frac{3}{32}$	$1\frac{13}{32}$	290	$64\frac{1}{8}$	$128\frac{1}{4}$	$135\frac{3}{4}$	$142\frac{1}{4}$	32	16·2
$2\frac{3}{8}$	$11\frac{5}{8}$	$8\frac{5}{16}$	$1\frac{7}{16}$	304	$67\frac{5}{8}$	$135\frac{1}{4}$	142·8	149·4	$33\frac{3}{4}$	16·1
$2\frac{7}{16}$	$11\frac{15}{16}$	$8\frac{17}{32}$	$1\frac{15}{32}$	319	$71\frac{1}{4}$	$142\frac{1}{2}$	$149\frac{7}{8}$	$156\frac{7}{8}$	$35\frac{5}{8}$	16·1
$2\frac{1}{2}$	$12\frac{1}{4}$	$8\frac{3}{4}$	$1\frac{1}{2}$	336	75	150	157	164·4	$37\frac{1}{2}$	16·0

original area of section, with a reduction in length of not less than 10 per cent. The steel pins for retaining the joining shackle-bolt, are to be capable of bearing a tensile stress not less than 35 tons per square inch, with a contraction at the fracture of not less than 45 per cent. of the original area. Mooring and close-link crane and rigging chains are to be proved to a stress of 8·47 tons per square inch of section of the sides of the link, or 466 pounds per circular ⅛ inch of section. Defective links are to be cut out and replaced. Stud-chain cables are to be proved according to the Act, as already described. Four-feet sample lengths of chain are to be tested for ultimate strength, which is not to be less than 16 tons per square inch of section of both sides of the links, or 880 pounds per circular ⅛-inch.

The 1½-inch mooring chain is made in lengths of 15 fathoms, with a joining shackle to each length, and a swivel for every 30 fathoms. The 1¼ inch, 1⅛ inch, 1 inch, and ⅞ inch mooring chains are in lengths of from 8 fathoms to 45 fathoms. Stud-chain cables are made in lengths of 12½ fathoms. The common links of mooring chains are 6 diameters in length, the breadth is 3·5 diameters. The ordinary end link is of iron, 1·2 diameters, 6½ diameters in length, 4·1 in breadth.

TABLE 221.—CHAIN MOORINGS, IN TEN-FATHOM LENGTHS: OPEN OR UNSTUDDED LINKS: SIZES, WEIGHT, AND PROOF-STRESS.

(Admiralty.)

Size, or Diameter of Iron at Sides of Link.	Greater Diameter at the Ends of Link.	Weight of Ten Fathoms.	Proof-Stress.
Inches	Inches.	Cwts.	Tons.
2¾	3·025	40	72
2⅞	3·162	45	79
3	3·3	50	86
3⅛	3·437	55	93
3¼	3·575	60	101
3½	3·85	75	117
3¾	4·125	87	134

Note.—The breaking stress must be not less than 1·40 times the proof stress; that is, 40 per cent. more.

TABLE 222.—CHAIN-RIGGING, CRANE CHAINS (SHORT LINK): SIZE AND WEIGHT.

(Admiralty.)

Size or Diameter of Iron.	Weight of One Fathom.	Size or Diameter of Iron.	Weight of One Fathom.	Size or Diameter of Iron	Weight of One Fathom.
Inches.	Pounds.	Inches.	Pounds.	Inches.	Pounds.
$\frac{1}{8}$	2	$\frac{9}{16}$	21	$1\frac{1}{8}$	73
$\frac{3}{16}$	3	$\frac{5}{8}$	25	$1\frac{1}{4}$	92
$\frac{1}{4}$	$4\frac{3}{4}$	$\frac{11}{16}$	30	$1\frac{3}{8}$	108
$\frac{9}{32}$	$5\frac{3}{4}$	$\frac{3}{4}$	36	$1\frac{1}{2}$	132
$\frac{5}{16}$	$6\frac{3}{4}$	$\frac{13}{16}$	39	$1\frac{5}{8}$	155
$\frac{3}{8}$	$9\frac{1}{2}$	$\frac{7}{8}$	48	$1\frac{3}{4}$	179
$\frac{7}{16}$	$13\frac{1}{4}$	$\frac{15}{16}$	53		
$\frac{1}{2}$	17	1	61		

TABLE 223.—SHORT-LINK CHAINS: WEIGHT AND CONDITIONS OF TEST.

(India Stores Department.)

Diameter of Iron.	Weight of One Fathom.	Proof Stress.	Load on Test Piece.	Elongation of Test Piece on Thirty-six Inches.
Inches.	Pounds.	Tons.	Tons.	Inches.
$\frac{1}{8}$	1	$\frac{3}{16}$	$\frac{7}{16}$	6
$\frac{3}{16}$	$2\frac{1}{4}$	$\frac{2}{5}$	1	7
$\frac{1}{4}$	$3\frac{3}{4}$	$\frac{3}{4}$	$1\frac{3}{4}$	$8\frac{1}{4}$
$\frac{5}{16}$	6	$1\frac{1}{8}$	3	$9\frac{1}{4}$
$\frac{3}{8}$	$8\frac{1}{2}$	$1\frac{5}{8}$	$4\frac{1}{4}$	$8\frac{5}{8}$
$\frac{7}{16}$	$11\frac{1}{2}$	$2\frac{1}{4}$	$5\frac{3}{4}$	$8\frac{3}{4}$
$\frac{1}{2}$	15	3	7	$7\frac{1}{8}$
$\frac{9}{16}$	19	$3\frac{3}{4}$	$8\frac{1}{2}$	$8\frac{1}{4}$
$\frac{5}{8}$	$23\frac{1}{2}$	$4\frac{5}{8}$	$11\frac{3}{4}$	10
$\frac{11}{16}$	$28\frac{1}{2}$	$5\frac{5}{8}$	$13\frac{3}{4}$	$8\frac{1}{4}$
$\frac{3}{4}$	34	$6\frac{3}{4}$	$16\frac{1}{4}$	$9\frac{1}{4}$
$\frac{13}{16}$	40	7·9	$18\frac{3}{4}$	$9\frac{3}{4}$
$\frac{7}{8}$	46	$9\frac{1}{8}$	22	$8\frac{7}{8}$
$\frac{15}{16}$	53	$10\frac{1}{2}$	$24\frac{1}{2}$	$8\frac{3}{8}$
1	60	12	29	$8\frac{7}{16}$
$1\frac{1}{8}$	76	$15\frac{1}{8}$	$36\frac{1}{4}$	$8\frac{5}{8}$
$1\frac{1}{4}$	94	$18\frac{3}{4}$	$41\frac{3}{4}$	$9\frac{3}{4}$
$1\frac{3}{8}$	114	$22\frac{5}{8}$	$51\frac{3}{4}$	$10\frac{5}{8}$
$1\frac{1}{2}$	135	27	64	$11\frac{3}{8}$

FRAMING.

Cranes.

When a crane *abc*, fig. 72, is loaded at *c* by the weight W, he stresses in the three members *ab*, *ac*, and *bc*, due to the oad, are measured proportionally by the respective lengths of these members; the vertical stress in the member *ab*, being equal to the load W. The diagonal and horizontal stresses increase with the overhang, as shown in fig. 73, by the increasing lengths of the diagonal and horizontal members, *bc''*, &c., and *ac''*, &c.; the vertical *ab* being constant.

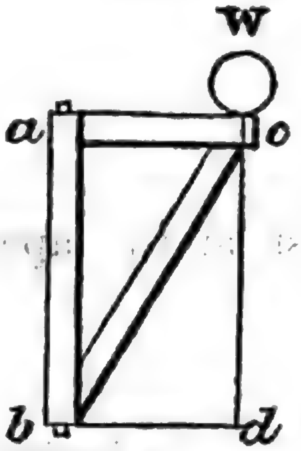

Fig. 72.—Crane.

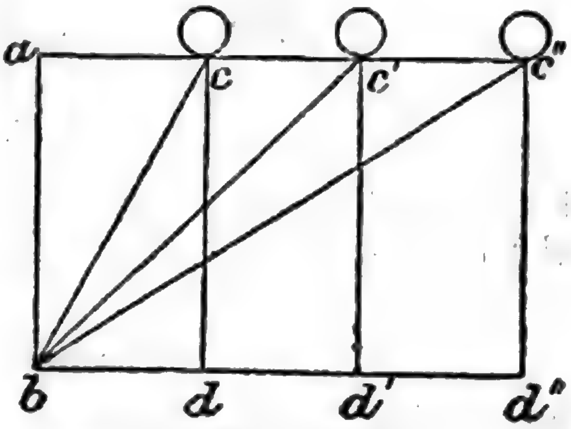

Fig. 73.—Crane.

Again, the diagonal stress increases proportionally with the obliquity of the jib *bc''*, &c., fig. 74, taken as constant in length.

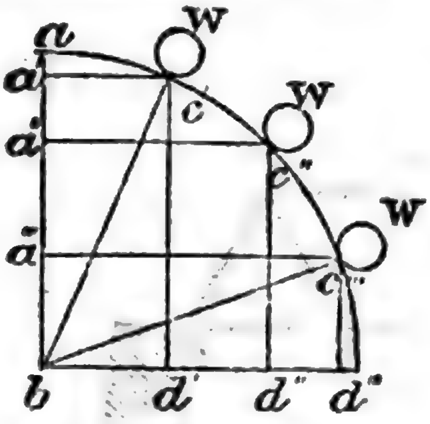

Fig. 74.—Crane.

Where both the diagonal and the tie member are oblique, as *bc* and *ac*, fig. 75, the stresses in the triangular figure, *abc*, as before, are measured proportionally by the lengths of the members; *ab* being the measure of the load W. The horizontal pull at *a*, is measured by the horizontal length *ac'*.

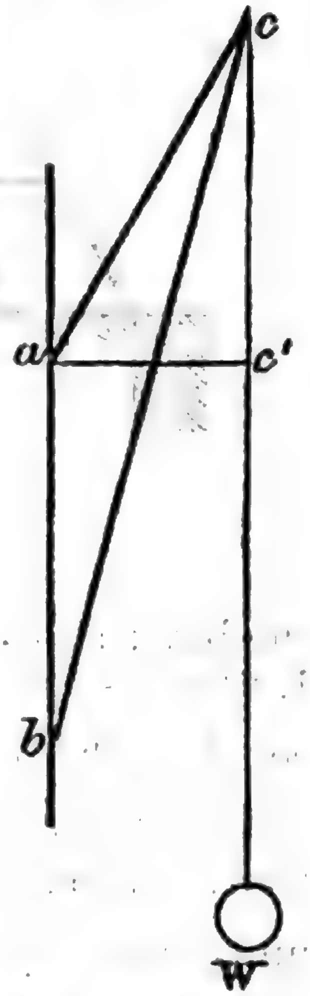

Fig. 75.—Crane.

Truss.

The truss or triangular frame *abc*, fig. 76, having equal limbs, *ac*, *bc*, supports the load W at the apex. In the parallelogram *acbe*, *ce* is the weight, *cd* is half the weight, and *ca* and *cb* are oblique compressive stresses. The horizontal tensional stress in *ab* is equal to the product of the weight by the span, divided

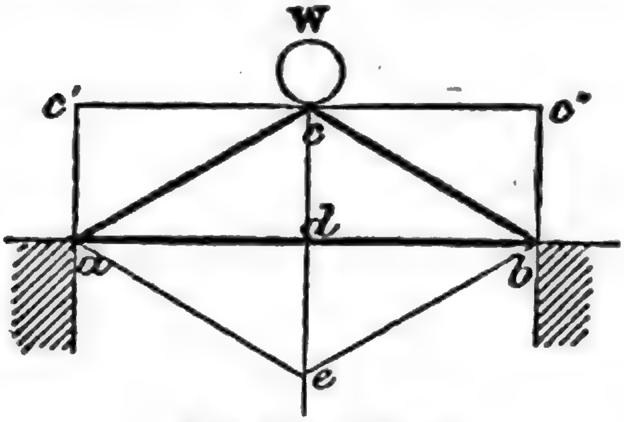

FIG. 76.—Truss.

by 4 times the rise. The horizontal thrust at the apex is equal to the tension in *ab*.

Framed Girders.

The tensional stress, or unit stress, in the extreme horizontal members *aa'* and *b'b*, fig. 77, showing a Warren girder. is equal to ·2885 W, in which W is the load at the centre. The stress, whether tensional or compressive, on any bay is equal to the product of the unit-stress by the order-number of the bay; above or below, reckoned from the extreme bay as 1, towards the middle. The stress on the central bay, also, is equal to the product of the unit-stress by $\frac{n+1}{2}$, in which n is the total number of bays. The stress on the middle pair of bays, tensional or compressive, is equal to the product of the unit-stress by $\frac{n-1}{2}$. In fig. 44, the stress on the central bay $e'c''$, is 1·731 W; in the central pair, it is 1·443 W. The stress in the braces is ·577 W, or twice the unit-stress in the flange.

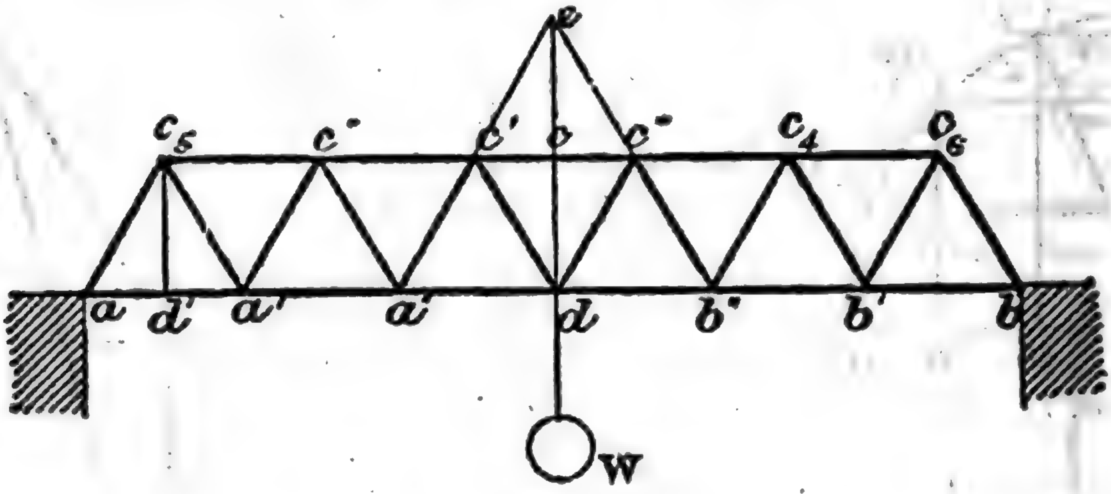

FIG. 77.—Warren Girder.

Truss Roofs.

In the ordinary triangular roof truss, *abc*, fig. 78, in which the total weight, including the load, is uniformly distributed, the tension in the horizontal member *ab*, is equal to $\frac{Wl}{8d}$, or the product of the weight by the span, divided by 8 times the rise. The horizontal thrust at the ridge *c* is equal to the tension in the horizontal tie.

When the horizontal tie, *ab*, is applied at any higher level, the tension in it is increased inversely as the depth *cd*.

In the A roof truss, fig. 45, there are two trusses, each of which goes to form half the roof, and the horizontal tierod E. Let the span *ab* be 40 feet, the rise 10 feet, and the depth *cd* 8 feet. The rafters *ac* and *bc* are 22·5 feet long; the struts F are 3·33 feet long, the tension bars C and D are 11·75 feet long. The weight on the couple is 8 tons, uniformly distributed, of which 4 tons is supported on each rafter, say 1 ton at *a*, the abutment, 2 tons at F, and 1 ton at the ridge *c*. The pressure at F, 2 tons, being vertical, is resolved, as indicated by diagram, into 1·8 tons stress on F, and ·875 tons on A. The stress on F is resolved into 3·18 tons on each of the tie-rods C and D. The tension in E is by formula $\frac{Wl}{8d}$, equal to $\frac{8 \times 40}{8 \times 8} = 5$ tons, which is resolved into 4¾ tons in C, and ·875 ton in F. This tension in F is resolved into 1·54 tons in each of C and D. Summing up the tensile stresses, there are (3·18 + 4·75 + 1·54 =) 9·47 tons in C; (3·18 + 1·54 =) 4·72 tons in D; and 5 tons in E.

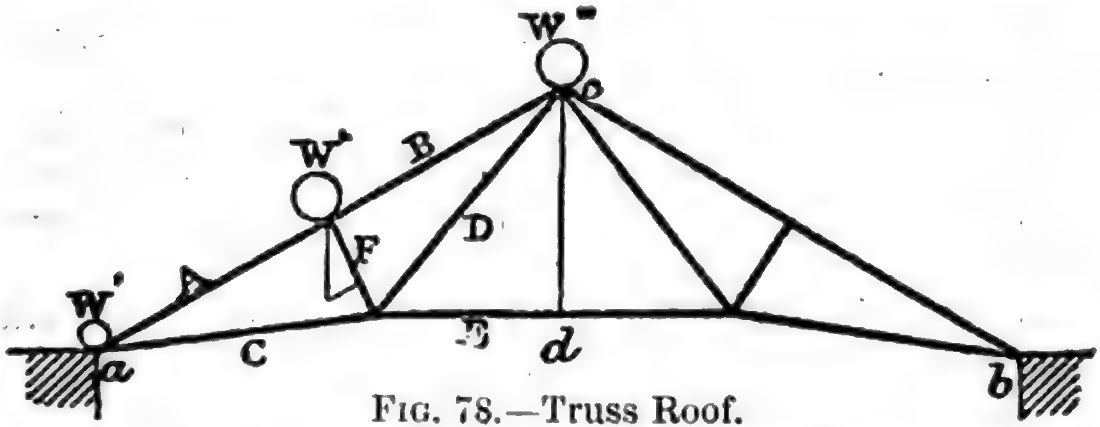

FIG. 78.—Truss Roof.

HARDNESS OF METALS, ALLOYS, AND STONES.

Messrs. F. Crace Calvert and R. Johnson tested the comparative hardness of metals by the indentation made by a steel point under pressure. The steel point was about ¼ inch long, 1¼ millimetres or ·049 inch wide at the point. Weights were added until the point entered to the extent of 3½ millimetres or ·128 inch in the course of half an hour. The Table 224 gives he comparative hardness of several metals; and Table 225 gives the result for several alloys of copper, zinc, tin, lead, nd antimony. The highest degree of hardness is that of cast ron, and it is, for the purpose of comparison, taken as 1000.

In the last column of the Table of alloys, the degree of ardness is calculated in terms of the elements separately, for imple mixtures.

The results from the alloys of copper and zinc, Table 225, No. 1, show that all the alloys having excess of copper are nuch harder than the metals composing them; and that ncrease of hardness is due to the zinc, the softer metal. But, f the zinc exceeds in proportion fifty per cent. of the alloy, he alloy becomes so brittle as to break as the point penetrates. The alloy $Zn\,Cu$, consisting of equal weights of copper and inc, is remarkable for its hardness, which is about three imes the calculated degree of hardness.

In section 4, of Table 225, may be noted the softness of the ronze with excess of tin. Also, that an increase of quantity f so malleable a metal as copper should so suddenly render he alloy brittle, until for $Sn\,Cu^{10}$, brittleness ceases, and the ardness is nearly equal to that of wrought iron.

In section 5, Table 225, it is notable that the calculated ardness of alloys of tin and zinc, is not very different from he actual hardness: indicating a state of simple mixture of he elements.

In Table 226, is given the comparative hardness of granites nd other stones according to M. Reynaud.

TABLE 224.—COMPARATIVE HARDNESS OF METALS.
(F. Crace Calvert & R. Johnson.)

Metal.	Comparative Hardness Cast Iron = 1000.
Cast Iron, Staffordshire cold-blast, grey, No. 3	1000
Steel	958
Wrought Iron (made from above cast iron)	948
Platinum	375
Copper, pure	301
Aluminium	271
Silver, pure	208
Zinc, ,,	183
Gold, ,,	167
Cadmium, pure	108
Bismuth, ,,	52
Tin, ,,	27
Lead, ,,	16

TABLE 225.—COMPARATIVE HARDNESS OF ALLOYS.

ALLOYS.	Proportions per cent., by Weight.	Comparative Hardness. Cast Iron =1000.	Calculated Hardness. Cast Iron =1000.
1. *Copper and Zinc.*			
$Zn\ Cu^5$	C 82·95 Z 17·05	427	281
$Zn\ Cu^4$	C 79·56 Z 20·44	469	277
$Zn\ Cu^3$	C 74·48 Z 25·52	469	276
$Zn\ Cu^2$	C 66·06 Z 33·94	473	261
$Zn\ Cu$	C 49·32 Z 50·68	604	243
$Cu\ Zn^2$	C 32·74 Z 67·26	Broke	...
$Cu\ Zn^3$	C 24·64 Z 75·36	”	...
$Cu\ Zn^4$	C 19·57 Z 80·43	”	...
$Cu\ Zn^5$	C 16·30 Z 83·70	”	...
2. *Lead & Antimony.*			
$Pb\ Sb^5$	L 24·31 A 75·69	Broke	...
$Pb\ Sb^4$	L 28·64 A 71·36	”	...
$Pb\ Sb^3$	L 34·86 A 65·14	...	...
$Pb\ Sb^2$	L 44·53 A 55·47	...	...
$Pb\ Sb$	A 38·39 L 61·61	...	...
$Pb\ Sb^2$	A 23·68 L 76·32	...	...
$Pb\ Sb^3$	A 17·20 L 82·80	...	...
$Pb\ Sb^4$	A 13·48 L 86·52	...	...
$Pb\ Sb^5$	A 11·08 L 88·92	...	...

TABLE 225.—COMPARATIVE HARDNESS OF ALLOYS (*cont.*).

ALLOYS.	Proportions per cent., by Weight.	Comparative Hardness. Cast Iron = 1000.	Calculated Hardness. Cast Iron = 1000.
3. *Commercial Brasses.*			
"Large bearings"	Copper 82·05 Tin 12·82 Zinc 5·13	562	259
Mud plugs	Copper 80 Tin 10 Zinc 10	750	262
Yellow brass	Copper 64 Zinc 56	520	258
Pumps and pipes	Copper 80 Tin 5 Zinc 7·5 Lead 7·5	343	257
4. *Copper and Tin (Bronze).*			
$\mathrm{Cu\ Sn^5}$	C 9·73 T 90·27	83	52
$\mathrm{Cu\ Sn^4}$	C 11·86 T 88·14	96	60
$\mathrm{Cu\ Sn^3}$	C 15·21 T 84·79	104	69
$\mathrm{Cu\ Sn^2}$	C 21·21 T 78·79	135	85
$\mathrm{Cu\ Sn}$	C 34·98 T 65·02	Broke	...
$\mathrm{Sn\ Cu^2}$	T 51·83 C 48·17	"	...
$\mathrm{Sn\ Cu^3}$	T 38·29 C 61·79	"	...
$\mathrm{Sn\ Cu^4}$	T 31·73 C 68·27	"	...
$\mathrm{Sn\ Cu^5}$	T 27·10 C 72·90	"	...
$\mathrm{Sn\ Cu^{10}}$	T 15·68 C 84·32	917	257
$\mathrm{Sn\ Cu^{15}}$	T 11·03 C 88·97	773	271
$\mathrm{Sn\ Cu^{20}}$	T 8·51 C 91·49	640	278
$\mathrm{Sn\ Cu^{25}}$	T 6·83 C 98·17	602	279

TABLE 225.—COMPARATIVE HARDNESS OF ALLOYS (*cont.*).

ALLOYS.	Proportions per cent., by Weight.	Comparative Hardness. Cast Iron =1000.	Calculated Hardness. Cast Iron =1000.
5. *Tin and Zinc.*			
$Zn\ Sn^2$ . . .	Z 21·65 T 78·35	65	61
$Zn\ Sn$ . .	Z 35·60 T 64·40	69	83
$Sn\ Zn^2$ . . .	Z 47·49 T 52·51	83	110
$Sn\ Zn^3$ . .	Z 37·57 T 62·43	94	125
$Sn\ Zn^4$ . . .	Z 31·14 T 68·86	105	131
$Sn\ Zn^5$ . .	Z 26·57 T 73·43	125	142
$Sn\ Zn^6$ . . .	Z 15·32 T 84·68	121	158
6. *Lead and Tin.*			
$Pb\ Sn^5$ . . .	L 26·03 T 73·97	42	24
$Pb\ Sn^4$ . .	L 30·57 T 69·43	41	24
$Pb\ Sn^3$ . . .	L 36·99 T 63·01	32	23
$Pb\ Sn^2$ . .	L 46·82 T 53·18	26	20
$Pb\ Sn$ . . .	L 63·78 T 36·22	21	20
$Sn\ Pb^2$ . .	T 22·11 L 77·89	26	18
$Sn\ Pb^3$ . . .	T 15·91 L 84·09	21	17
$Sn\ Pb^4$ . .	T 12·43 L 87·57	26	17
$Sn\ Pb^5$ . . .	T 10·20 L 89·80	23	17

TABLE 226.—COMPARATIVE HARDNESS OF STONES. (Reynaud.)

Stone.	Comparative Hardness: White-veined Marble = 1.
White-veined marble	1·00
Syenite (red granite)	10·08
Green granite	9·70
Granite (deadleaf)	9·30
Grey granite of the Vosges	8·92
„ „ Bretagne	8·56
„ „ Normandy	7·00
Dark grey marble	1·28
Lias limestone	·88

The following scale of hardness is that adopted by the Technical High School at Prague. The substances are arranged in ascending order, from the softest to the hardest. The test is made by drawing a conically pointed cylindrical piece of one of the metals tabulated along a polished surface of the metal to be tested. If the pointed pieces become blunted without marking the surface, the metal under test is harder than the pointed pieces employed. If neither point nor metal surface be abraded, the hardness is taken as equal. If the surface be scratched, the metal under test is taken as softer than the pointed metal:—

1. Pure soft lead.
2. Pure tin.
3. Pure hard lead.
4. Pure annealed copper.
5. Fine cast copper.
6. Soft bearing metal (copper, 85; tin, 10: zinc, 5).
7. Cast iron (annealed).
8. Fibrous wrought iron.
9. Fine grained light grey cast iron.
10. Toughened cast iron (melted with 10 per cent. of wrought-iron turnings).
11. Soft ingot iron, having ·15 per cent. of carbon (will not harden).
12. Steel, having ·45 per cent. of carbon (not hardened).
13. Steel, having ·96 per cent. of carbon (not hardened).
14. Crucible cast steel, hardened and tempered blue.
15. Crucible steel, hardened and tempered violet to orange-yellow.

16. Crucible steel, hardened and tempered straw-yellow.
17. Hard bearing metal (copper 83, tin 17).
18. Crucible steel, glass hard.

LABOUR OF ANIMALS.

Men.—The average net daily work of an ordinary labourer at a pump, a winch, or a crane, may be taken at 3,300 foot-pounds per minute, for 8 hours a day. But, for shorter periods, from four to five times the rate may be exerted.

Horses and Bullocks.—Boulton and Watt estimated that a dray-horse could exert a power of 33,000 foot-pounds per minute, for 8 hours a day. Rennie's estimate of the average work of horses, strong and weak, was at the rate of 22,000 foot-pounds per minute for 8 hours a day.

A pair of well-fed bullocks can raise water at the rate of 8,000 foot-pounds per minute, for a morning's work of 4½ hours.

MECHANICAL PRINCIPLES.

THE statical *moment* of a force or of a body, with respect to a given point, or axis, or plane, is expressed by the product of the weight of the body by its perpendicular distance from the point, axis, or plane.

In *levers*, the moment of the weight or resistance about the fulcrum, is equal to the moment of the power or force applied to counteract the resistance. Let P = the power, W = the weight or resistance, L and l respectively the lengths of the arms of the lever, taken as straight, then

$$\text{the moment } P \times L = \text{the moment } W \times l,$$

and any one of the four quantities P, L, W, and l, can be found by a simple adaptation of the above equation, thus :—

$$P = \frac{W \times l}{L} \quad . \quad . \quad . \quad . \quad (1)$$

$$W = \frac{P \times L}{l} \quad . \quad . \quad . \quad . \quad (2)$$

$$L = \frac{W \times l}{P} \quad . \quad . \quad . \quad . \quad (3)$$

$$l = \frac{P \times L}{W} \quad . \quad . \quad . \quad . \quad (4)$$

In these equations, it is assumed that the power and resistance act on the lever at right angles to it. If the lever be bent, or if the forces act obliquely, equilibrium or equality of moments may be maintained. Draw a horizontal line through the fulcrum to meet the vertical lines through the power and the weight. The moments of the power and the weight are calculated on the horizontal lengths, and they are equal to each other.

If two or more levers are connected consecutively one to the other, as one system, and the power and the weight are applied at the two extremes, in equilibrium, the power is to the weight as the compound inverse ratio of the levers. Suppose, for instance, the arms of the levers are successively as 3 to 1, 4 to 1, and 5 to 1, the compound ratio is the product of the three ratios, or it is as ($3 \times 4 \times 5 =$) 60 to 1; and the power is to the weight as 1 to 60.

In simple *pulleys* on fixed bearings, there is no leverage, or augmentation of force; they simply transmit power, or change its direction. They act as levers having arms of equal lengths. But the pulley may be employed so as to augment the leverage, by suspending the weight to the axis of the pulley, and fixing one end of the cord, and pulling at the other end. The leverage is as 2 to 1, in this case: the weight acting at the length of the radius of the pulley from the fixed cord, and the power at the length of the diameter.

Pulleys may be combined in a pair of blocks, or sets of two or more on one axis; of which one block is fixed in position, and the other is moveable, taking the weight. The rope is usually fixed by one end to the stationary block, and is passed over the fast and moveable pulleys successively, the power being applied to the loose end. The force required at the loose end of the rope to balance the weight, irrespective of frictional and other external resistances, is equal to the quotient of the weight divided by the number of ropes by which it is carried, or the ropes proceeding from the moveable block. This number is equal to twice the number of moveable pulleys.

Conversely, to find the weight or resistance that will be balanced by a given power, irrespective of external resistances, multiply the power by the number of ropes proceeding from the moveable block.

When the fixed end of the rope is fastened to the moveable block, the divisor or multiplier is equal to twice the number of moveable pulleys plus 1.

The *wheel and axle* resemble two pulleys on one axis, having different diameters. If a weight be lifted by means of a rope wound over the axle or a roller on the axle, the power being applied at the rim of the wheel, the action is like that of a lever of which the shorter arm is equal to the radius of the axle plus half the thickness of the rope; and the longer arm is equal to the radius of the wheel. The power and the weight are to each other as the radial lengths inversely, irrespective of external resistance; or they are as the diameters inversely. As with the lever, so with the wheel and axle,

$$\text{the moment } P \times L = \text{the moment } W \times l,$$

in which P is the power or force at the circumference of the wheel, W the weight on the axle or barrel, and $L \times l$ respectively the radii of the wheel and the axle. Where,

$$P = \frac{W \times l}{L} \quad . \quad . \quad . \quad . \quad . \qquad (5)$$

$$W = \frac{P \times L}{l} \quad . \quad . \quad . \quad . \quad . \qquad (6)$$

On the inclined plane, if a weight be raised by a force applied parallel to the plane, the sides of the triangle formed by the plane, its base, and its height, are proportional respectively to the weight, the pressure of the weight on the plane, and the power applied.

Let l be the length of an inclined plane, and h the height, P the power, and W the weight drawn up the plane.

$$P = \frac{Wh}{l} \quad . \quad . \quad . \quad . \quad . \qquad (7)$$

$$W = \frac{Pl}{h} \quad . \quad . \quad . \quad . \quad . \qquad (8)$$

When the raising force is applied to the weight in a direction parallel to the base, the plane, its base, and its height are proportional respectively to the pressure of the weight on the plane, the weight, and the power applied.

The *wedge* is a pair of inclined planes united by their bases. The wedge is employed for the purpose of forcibly separating two bodies, or breaking or splitting a body; or for fastening bodies together. In the application of pressure to the head or butt-end of the wedge, to cause it to penetrate a resisting body, the power is to the resistance as the thickness of the wedge is to its length. Let t be the thickness, l the length, W the resistance, and P the power or pressure on the head of the wedge. Then,—

$$P = \frac{Wt}{l} \quad . \quad . \quad . \quad . \quad . \qquad (9)$$

$$W = \frac{Pl}{t} \quad . \quad . \quad . \quad . \quad . \qquad (10)$$

The *screw* is an inclined plane lapped round a cylinder. The effect of a screw is reckoned in terms of the pitch or height of the plane for one revolution, and the radius of the handle or wheel by which it is turned. The power applied at the end of the radius describes, for one turn of the screw, a circle of which the diameter is twice the radius. The circumference of the circle is equal to 6·28 times the radius, and the power is to the resistance as the pitch of the screw is to 6·28 times the radius of the power, or to 3·14 times the diameter. Let p be the pitch of the screw-thread, r the radius of the lever or wheel by which the power is applied, W the weight, load, or resistance on the screw, and P the power. Then.

$$6{\cdot}28\,\mathrm{P}r = \mathrm{W}p \quad . \quad . \quad . \quad . \quad . \qquad (11)$$

$$\mathrm{P} = \frac{\mathrm{W}p}{6{\cdot}28r} \quad . \quad . \quad . \quad . \quad . \qquad (12)$$

$$\mathrm{W} = \frac{6{\cdot}28\mathrm{P}r}{p} \quad . \quad . \quad . \quad . \quad . \qquad (13)$$

$$p = \frac{6{\cdot}28\mathrm{P}r}{\mathrm{W}} \quad . \quad . \quad . \quad . \quad . \qquad (14)$$

$$r = \frac{\mathrm{W}p}{6{\cdot}28\mathrm{P}} \quad . \quad . \quad . \quad . \quad . \qquad (15)$$

If the power be applied through a wheel, the diameter of the wheel may be substituted for the radius, when half the co-efficient—3·14—is to be employed in the formulæ.

The relations are the same whether the nut be turned upon the screw, or the screw be turned within the nut.

Mechanical Centres.

There are various mechanical centres in solid or quasi-solid bodies—the centre of gravity, the centre of gyration, the centre of oscillation. The first is statical; the second and third are dynamical, inasmuch as these are only developed in bodies in motion.

Centre of Gravity.

The centre of gravity of a body is that point within the body about which the gravitation of the particles of the body is self-balanced. It is a resultant centre of action, at which the body may be supposed to be concentrated: at which it can be freely supported or suspended in any position in a state of rest. In various classes of calculation the whole weight or mass of a body is taken as massed at the centre of gravity when at rest, or when in motion rectilineally.

The centre of gravity of regular plane figures or solids—as, for instance, a straight line, a square, a parallelogram, a regular polygon, a circle, the circumference of a circle, an ellipse, a prism, a cylinder, a ring, a sphere, a spheroid, a regular solid—is the same as the geometrical centre.

The centre of gravity of a plane triangle is found by drawing a straight line from one of the angles to the middle of the opposite side, and setting off one-third of this line from the side. Or, drawing two such straight lines from two of the angles, their intersection is the centre of gravity.

The centre of gravity of a trapezium is found by drawing the diagonals, and joining the centres of each alternate pair of triangles so formed. The final intersection is the centre of gravity.

In a cone or a pyramid, the centre of gravity is in the axis, at a distance of one-fourth of its length from the base.

For an arc of a circle, multiply the bisecting radius by the chord of the arc, and divide by the length of the arc. The quotient is the distance of the centre of gravity from the centre of the circle.

For a segment of a circle, cube the chord and divide by 12 times the area of the segment. The quotient is the distance of the centre of gravity from the centre of the circle.

In a sector of a circle, the centre of gravity is two-thirds of the distance of that of an arc, from the centre of the circle. Or, multiply the radius by twice the chord of the arc, and divide by three times the length of the arc; the quotient is the distance of the centre of gravity from the centre of the circle.

In a semicircle, multiply the radius by ·4244; the product is the distance of the centre of gravity from the centre of the circle.

In a solid hemisphere, the centre of gravity is at a distance of three-eighths of the radius from the centre.

For a solid spherical segment, deduct half the versed sine from the radius, and square the difference; multiply this square by the square of the versed sine and by 3·1416; and divide by the content of the segment. The quotient is the distance of the centre of gravity from the centre of the segment.

In a hemispherical surface, spherical-segment surface, or spherical-zone surface, the centre of gravity is at half the height of the axis.

In a parabola, the centre of gravity is in the axis, at a distance of three-fifths of the height from the vertex.

In a semiparabola, the centre of gravity is at the same height as in a parabola, but it is situated at a distance from the axis, of three-eighths of the semibase.

In a paraboloid, the centre of gravity is in the axis, at a distance of two-thirds of the axis from the vertex.

For two bodies, fixed one at each end of a straight bar, the common centre of gravity is in the bar, at that point which divides the distance between their respective centres of gravity in the inverse ratio of the weights. In this solution, the weight of the bar is not reckoned for. But it may be taken as a third body, and allowed for as in the following directions.

For more than two bodies connected in one system, find the common centre of gravity of two of them; and find the common centre of these two jointly with a third body, and so on to the last body of the group.

For any plane figure, the centre of gravity may be found mechanically, by suspending the figure by any point near its edge, and marking on it the direction of a plumb-line hung from that point; then suspending it from some other point near the edge, and again marking the direction of the plumb-line. The intersection of the directions is the centre of gravity.

Centre of Gyration.

The centre of gyration, revolution, or whirling, is the resultant centre of the force or work accumulated in the revolving mass; so situated that if all parts of the body were concentred there, the work accumulated in the body, at the same angular speed, would be the same as in the original body. To find the position of this point, the centre of gyration, suppose the revolving body to consist of an indefinitely great number of equal particles; as the work accumulated in each particle is proportional to the square of its velocity, and as the velocity is proportional to the radius of revolution, or distance of the particle from the axis of revolution, the work in each particle is proportional to the square of its distance from the axis. Multiply the weight of each particle by the square of its distance from the axis: the product is the moment of inertia of the particle, and the sum of all the products is the moment of inertia of the whole mass. Divide the moment of inertia by the weight of the body; the quotient is the square of the radius of gyration, or of the distance of the resultant centre of gyration from the axis; and the square root of the quotient is the radius of gyration. The moment of inertia is usually represented by the symbol I. Let the total revolving weight equal w, and the radius of gyration equal *r*. The relations of these quantities are expressed thus :—

$$I = wr^2 \quad . \quad . \quad . \quad . \quad (16)$$

$$\frac{I}{w} = r^2 \quad . \quad . \quad . \quad . \quad . \quad (17)$$

$$r = \sqrt{\frac{I}{w}} \quad . \quad . \quad . \quad . \quad . \quad (18)$$

Concisely expressed thus :—

The moment of inertia is equal to the product of the weight by the square of the radius of gyration.

The moment of inertia divided by the weight is equal to the square of the radius of gyration.

The radius of gyration is equal to the square root of the quotient of the moment of inertia divided by the weight.

In calculating the radius of gyration, it is advisable in practice to divide the body into a considerable number of small parts—the more numerous the more nearly exact is the result. When these parts are equal, the radius of gyration may be determined by simply taking the mean of all the squares of the distances of the parts from the axis of revolution, and finding the square root of the mean square.

The radius of gyration of a straight bar, revolving about one end, is equal to the length of the bar multiplied by ·5773.

That of a thin rectangular plate revolving facewise on one of its edges, is equal to the radial length of the plate multiplied by ·5773.

That of a straight bar or a thin rectangular plate, revolving about its mid-length or centre, is equal to the length multiplied by ·2886.

That of a straight bar or a thin rectangular plate revolving on any point between the extremities, is, generally, equal to $\sqrt{\frac{a^3 + b^3}{3(a+b)}}$, in which *a* and *b* are the lengths of the two parts of the bar or plate. That is to say, divide the sum of the cubes of the two sub-lengths, by three times the length of the bar ; the square root of the quotient is equal to the radius of gyration.

That of a circular plate, a solid wheel of uniform thickness, or a solid cylinder of any length, revolving on its axis, is equal to the geometrical radius multiplied by ·7071.

That of a flat ring or hollow cylinder revolving on its axis, is equal to $\sqrt{\frac{R^2 + r^2}{2}}$, in which R and *r* are the outer and inner geometrical radii of the ring. That is to say, the radius of gyration is equal to the square root of half the sum of the squares of the inner and outer radii.

That of the circumference of a circle revolving about its axis, is equal to the geometrical radius.

That of the circumference of a circle revolving about a diameter, is equal to the geometrical radius of the circle multiplied by ·7071.

That of a very thin circular plate revolving about one of its diameters, is equal to half the geometrical radius of the circle.

That of a solid cylinder revolving on a diameter at mid-length, is equal to $\sqrt{\frac{l^2}{12}+\frac{r^2}{4}}$, in which l and r are the length and the geometrical radius respectively. That is to say, divide the square of the length by 12, and the square of the radius by 4; the radius of gyration is equal to the square root of the sum of the quotients.

That of a hollow cylinder revolving on a diameter at mid-length is equal to $\sqrt{\frac{l^2}{12}+\frac{R^2+r^2}{4}}$, in which l, R, and r, are the length, and the outer and the inner geometrical radius respectively. That is to say, divide the square of the length by 12, and the sum of the squares of the inner and outer radii by 4; the radius of gyration is equal to the square root of the sum of these two quotients.

That of a very thin hollow cylinder revolving on a diameter at mid-length, is equal to $\sqrt{\frac{l^2}{12}+\frac{R^2}{2}}$, in which l and R are the length and the outer geometrical radius of the cylinder respectively. That is to say, divide the square of the length by 12, and the square of the radius by 2; the radius of gyration is equal to the square root of the sum of the quotients.

That of a solid sphere revolving about a diameter, is equal to the geometrical radius of the sphere multiplied by ·6325.

That of a hollow sphere revolving about a diameter is equal to $\sqrt{\frac{2(R^5-r^5)}{5(R^3-r^3)}}$, in which R and r are the outer and inner geometrical radii respectively. That is to say, divide twice the difference of the fifth powers of the radii by five times the difference of the cubes of the radii; the radius of gyration is equal to the square root of the quotient.

That of the surface of a sphere, or a very thin hollow sphere, revolving about a diameter, is equal to the geometrical radius of the sphere multiplied by ·8165.

That of a solid cone revolving about its axis is equal to the geometrical radius of the base multiplied by ·5477.

That of a solid cone revolving about its vertex is equal to $\sqrt{\frac{12l^2+3r^2}{20}}$, in which l is the length, and r is the geometrical radius of the base. That is to say, to 12 times the square of the length add 3 times the square of the radius; divide the sum of these by 20; the radius of gyration is equal to the square root of the quotient.

When the cone is right-angled—the radius of the base being equal to the length,—the radius of gyration is equal to the length multiplied by ·8660.

That of a paraboloid revolving on the axis is equal to the geometrical radius of the base multiplied by ·5773.

That of a parallelopiped revolving in its own plane about one of the ends at a point midway of its breadth, is equal to $\sqrt{\frac{4l^2+b^2}{12}}$, in which l is the length, and b the breadth. That is to say, to 4 times the square of the length add the square of the breadth, and divide the sum by 12; the radius of gyration is equal to the square root of the quotient.

Centre of Oscillation.

The centre of oscillation of a body vibrating about a fixed axis or point of suspension, by the action of gravity, is the resultant centre of the force or work alternately accumulated and neutralised by gravitation in the oscillating mass during each vibration. It is so situated that if all parts of the body were concentrated there, the quantity of work alternately accumulated and neutralised would continue unaltered, and the body would continue to vibrate in the same time. The centre of oscillation is in the straight line which joins the centre of gravity to the axis of oscillation. The particles of the body have velocities varying with the distance of the particles from the axis, and if the moment of inertia of the body, the method of finding which has already been explained, be divided by the weight of the body, and by the distance of the centre of gravity from the centre of suspension, the quotient will be the length of the resultant radius of oscillation, at the end of which is the centre of oscillation. Putting I and w, as before, for the moment of inertia and the weight of the body respectively, r/o for the radius of oscillation, and r/g for the radius of the centre of gravity, then,—

$$r/o = \frac{I}{w \times r/g} \quad . \quad . \quad . \quad . \quad (19)$$

$$\text{and } r/o \times r/g = \frac{I}{w} \quad . \quad . \quad . \quad . \quad (20)$$

But $\frac{I}{w}$ is equal to $\sqrt{\frac{I}{w}} \times \sqrt{\frac{I}{w}}$, or $(r \times r)$, the square of the radius of gyration, consequently,

$$r/g : r :: r : r/o \quad . \quad . \quad . \quad . \quad (21)$$

That is to say, the radius of oscillation is a third proportional to the radius of the centre of gravity and the radius of gyration, and finally,

$$\text{Radius of oscillation} = \frac{\text{radius}^2 \text{ of gyration}}{\text{radius of centre of gravity}} \quad . \quad (22)$$

In a straight line, or a uniform thin bar or cylinder, suspended by one end, oscillating about it as an axis, the centre of oscillation is at $\frac{2}{3}$rds of the length of the rod from the axis.

In a straight line or thin bar of uniform thickness, but in which the density of its particles increase as the distance from the axis, the centre of oscillation is at $\frac{3}{4}$ths of the length of the rod from the axis.

In a straight line or uniform thin bar, suspended at a point one-third of the length below the upper end of the bar, the centre of oscillation is at $\frac{2}{3}$rds of the length below the axis, or it is coincident with the lower end of the bar. That is to say, whether a thin bar be suspended at one end or at a point one-third of its length below the upper end, the vibrations will be performed in the same time. The limit of transition of the axis is at half the length of the bar, round which point it does not oscillate at all, the centre of oscillation being indefinitely removed.

The lengths of the radius of oscillation of a few regular plane figures or thin plates, suspended by the vertex or uppermost point, are as follows :—

1st. When the vibrations are flatwise, or perpendicular to the plane of the figure :

In an isosceles triangle the radius of oscillation is equal to $\frac{3}{4}$ths of the height of the triangle.

In a circle, $\frac{5}{8}$ths of the diameter.

In a parabola, $\frac{5}{7}$ths of the height.

2nd. When the vibrations are edgewise, or in the plane of the figure :

In a circle the radius of oscillation is $\frac{3}{4}$ths of the diameter.

In a rectangle suspended by one angle, $\frac{2}{3}$rds of the diagonal.

In a parabola, suspended by the vertex, $\frac{5}{7}$ths of the height, plus $\frac{1}{3}$rd of the parameter.

In a parabola, suspended by the middle of the base, $\frac{4}{7}$ths of the height plus $\frac{1}{2}$ the parameter.

In a sector of a circle suspended by the centre, $\frac{3}{4}$ths of the geometrical radius multiplied by the length of the arc, and divided by the length of the chord.

The length of the radius of oscillation of a cone is $\frac{4}{5}$ths of the height, plus the quotient obtained by dividing the square of the radius of the base by five times the height. If a right-angled cone be suspended at its vertex, the centre of oscillation will coincide with the centre of its base, and the cone will vibrate in the same time as a simple pendulum of which the length is equal to the height of the cone.

That of a sphere suspended by a cord is $\frac{2}{5}$ths of the square of the geometrical radius, divided by the length of the cord measured to the centre of the sphere, plus the length of the chord so taken. For example, in a sphere 8 inches in diameter, suspended by a cord or a light rod 20 inches long, as measured between the centre of suspension and the centre of the sphere, the radius of oscillation is equal to,—

$$\frac{2 \times 4^2}{5 \times 20} + 20 = {\cdot}32 + 20 = 20{\cdot}32 \text{ inches,}$$

or ·32 inch below the centre of the sphere.

If the point of suspension be at the surface of the sphere, or at the extremity of a geometrical radius, the radius of oscillation is equal to $\frac{7}{5}$ths of the radius, or $\frac{7}{10}$ths of the diameter.

Centre of Percussion.

The centre of percussion of a body oscillating or vibrating about a fixed axis, is identical with the centre of oscillation, which is the point at which, if a blow is struck, the percussive action is the same as if the whole mass of the body were concentrated at the point.

The Pendulum.

A "simple pendulum" is defined as a heavy particle attached to one end of a cord or a rod without weight, and caused to vibrate on the centre of suspension. The time of vibration of an ordinary pendulum depends on the angle or arc of vibration; but for arcs of vibration not exceeding 4 or 5 degrees, the time of vibration is sensibly the same for any length of arc within that limit. This uniformity of time of vibration is called isochronism.

The length or radius of oscillation of the pendulum vibrating seconds, at the level of the sea, in the latitude of London, is 39·1393 inches. The lengths for other places are given

TABLE 227.—GRAVITY; LENGTH OF SECONDS PENDULUM.

Locality.	Latitude.		Force of Gravity at the Level of the Sea: Value of g.	Length of Pendulum beating Seconds, at the Level of the Sea.
	Degs.	Secs.	Feet per Second.	Feet.
Equator	0	0	32·091	3·2514
Latitude 45°	45	0	32·173	3·2597
Paris	48	50	32·183	3·2609
Greenwich (London)	51	29	32·191	3·2616
Berlin	52	30	32·194	3·2619
Dublin	53	21	32·196	3·2621
Manchester	53	29	32·196	3·2622
Edinburgh	55	57	32·203	3·2629
Aberdeen	57	9	32·206	3·2632
Pole	90	0	32·255	3·2682

The relations of time, height of fall, and velocity, are expressible as follows:—

Total time as	1, 2, 3, 4, &c.
Velocity acquired as	1, 2, 3, 4, &c.
Height of Fall as	1, 4, 9, 16, &c.
Or as	$1, 2^2, 3^2, 4^2$, &c.

Whilst the velocity is increased simply with the time, the height fallen increases as the square of the time, and as the square of the velocity. These relations are formulated in the following rules, in which,—

t = time, in seconds.
h = height fallen, in feet.
v = velocity acquired, in feet per second.

RULE 1.—To find the *velocity acquired*, given the height of fall, multiply the height by 64·4, and take the square root of the quotient.

Or, multiply the square root of the height by 8. The exact value of the coefficient is 8·025, but 8 is usually taken for ordinary calculations.

These rules are formulated thus:—

$$v = \sqrt{64 \cdot 4\, h} \quad (30)$$

$$\text{Or } v = 8\sqrt{h} \quad (31)$$

RULE 2.—To find the *velocity acquired*, given the time of fall. Multiply the time in seconds by 32·2. Or,

$$v = 32 \cdot 2\, t \quad (32)$$

Rule 3.—To find the *height of fall*, given the velocity acquired. Square the velocity, and divide by 64·4. Or,

$$h = \frac{v^2}{64·4} \quad . \quad . \quad . \quad . \quad . \quad (33)$$

Rule 4.—To find the *height of fall*, given the time. Multiply the square of the time by 16·1. Or,

$$h = 16·1\,t^2 \quad . \quad . \quad . \quad . \quad (34)$$

Rule 5.—To find the *height of fall*, given the velocity and the time. Multiply the velocity by the time, and divide by 2. Or,

$$h = \frac{vt}{2} \quad . \quad . \quad . \quad . \quad . \quad (35)$$

Rule 6.—To find the *time of fall*, given the velocity acquired. Divide the velocity by 32·2. Or,

$$t = \frac{v}{32·2} \quad . \quad . \quad . \quad . \quad . \quad (36)$$

Rule 7.—To find the *time of fall*, given the height. Divide the height by 16·1; and find the square root of the quotient.

Or, multiply the square root of the height by ·2492.

Or, take one-fourth of the square root of the height, to find the time very nearly (within one-tenth of one per cent. of error by excess). Or,

$$t = \sqrt{\frac{h}{16·1}} \quad . \quad . \quad . \quad (37)$$

$$\text{Or, } t = ·2492\sqrt{h} \quad . \quad . \quad . \quad . \quad . \quad (38)$$

$$\text{Or, } t = \tfrac{1}{4}\sqrt{h} \text{ (very nearly)} \quad . \quad (39)$$

The above rules, drawn for falling bodies, are available also for the case of bodies projected freely upwards in opposition to gravity and uniformly retarded by it. The symbol v is expressive of the initial velocity with which the ascending body is propelled; h is the height to which it rises; t is the time of ascent.

The formula (33) for the height due to the velocity may be adapted for finding the head due to a velocity v_1 expressed in miles per hour. A speed of 1 mile per hour is equivalent to 1·46 feet per second, and the formula becomes by substitution, $h = \frac{1·46 v_1^2}{64·4}$.

By reduction, the following rule is obtained :—

Rule 7.—To find the *height* due to the velocity or speed in miles per hour. Divide the square of the speed by 29·94. Or

$$h = \frac{v_1^2}{29·94} \quad . \quad . \quad . \quad . \quad . \quad (40)$$

The following table contains the times of fall, and the final velocities due to given heights of fall; Table 229 gives, conversely, the heights of fall due to given velocities; Table 230 gives the heights of fall and the final velocities due to given times of fall; Table 231 gives the heights of fall due to given speeds in miles per hour.

TABLE 228.—FALLING BODIES:—HEIGHT OF FALL, AND CORRESPONDING TIME OF FALL, AND FINAL VELOCITY.

$t = \cdot 2492\sqrt{h}$. $v = 8\cdot 025\sqrt{h}$.

Height of Fall.	Time of Fall.	Velocity acquired in Feet per Second.	Height of Fall.	Time of Fall.	Velocity acquired in Feet per Second.	Height of Fall.	Time of Fall.	Velocity acquired in Feet per Second.
Feet.	Secs.	Feet per Sec.	Feet.	Secs.	Feet per Sec.	Feet.	Secs.	Feet per Sec.
·01	·025	·803	1·4	·295	9·50	4·5	·529	17·03
·02	·035	1·14	1·5	·305	9·83	4·6	·534	17·21
·03	·043	1·39	1·6	·315	10·15	4·7	·540	17·40
·04	·050	1·61	1·7	·325	10·46	4·8	·546	17·58
·05	·056	1·80	1·8	·334	10·77	4·9	·552	17·78
·06	·061	1·97	1·9	·344	11·06	5·0	·557	17·99
·07	·066	2·12	2·0	·353	11·35	5·25	·571	18·41
·08	·071	2·27	2·1	·361	11·63	5·5	·585	18·82
·09	·075	2·41	2·2	·370	11·90	5·75	·598	19·24
·1	·079	2·54	2·3	·378	12·17	6·0	·611	19·66
·15	·097	3·11	2·4	·386	12·43	6·25	·623	20·07
·2	·112	3·59	2·5	·394	12·69	6·5	·635	20·46
·25	·125	4·01	2·6	·402	12·94	6·75	·647	20·85
·3	·137	4·40	2·7	·410	13·19	7·0	·659	21·23
·35	·147	4·75	2·8	·417	13·43	7·25	·672	21·61
·4	·158	5·07	2·9	·424	13·67	7·5	·683	21·97
·45	·167	5·38	3·0	·432	13·90	7·75	·694	22·33
·5	·176	5·68	3·1	·439	14·13	8·0	·705	22·69
·55	·185	5·95	3·2	·446	14·36	8·25	·716	23·05
·6	·193	6·22	3·3	·453	14·58	8·5	·727	23·40
·65	·201	6·47	3·4	·459	14·80	8·75	·737	23·74
·7	·209	6·71	3·5	·466	15·01	9·0	·746	24·07
·75	·216	6·95	3·6	·473	15·22	9·25	·757	24·40
·8	·223	7·18	3·7	·480	15·43	9·5	·768	24·73
·85	·230	7·40	3·8	·486	15·64	9·75	·778	25·06
·9	·236	7·61	3·9	·492	15·85	10	·788	25·38
·95	·243	7·82	4·0	·498	16·05	10·5	·808	26·01
1·0	·249	8·03	4·1	·505	16·25	11	·827	26·62
1·1	·261	8·42	4·2	·511	16·45	11·5	·845	27·22
1·2	·273	8·79	4·3	·517	16·64	12	·863	27·80
1·3	·284	9·15	4·4	·523	16·84	12·5	·881	28·37

TABLE 228.—FALL, TIME, AND VELOCITY (*continued*).

Height of Fall.	Time of Fall.	Velocity acquired in Feet per Second.	Height of Fall.	Time of Fall.	Velocity acquired in Feet per Second.	Height of Fall.	Time of Fall.	Velocity acquired in Feet per Second.
Feet.	Secs.	Feet per Sec.	Feet.	Secs.	Feet per Sec.	Feet.	Secs.	Feet per Sec.
13	·899	28·93	43	1·634	52·62	160	3·152	101·5
13·5	·916	29·49	44	1·653	53·23	170	3·250	104·6
14	·933	30·03	45	1·672	53·83	180	3·344	107·9
14·5	·949	30·56	46	1·690	54·43	190	3·435	110·6
15	·965	31·08	47	1·709	55·02	200	3·525	113·5
15·5	·981	31·59	48	1·727	55·60	225	3·738	120·4
16	·997	32·00	49	1·745	56·17	250	3·941	126·9
16·1	1·000	32·20	50	1·762	56·74	275	4·133	133·1
16·5	1·013	32·60	52	1·797	57·87	300	4·317	139·0
17	1·028	33·09	54	1·831	58·97	325	4·493	144·7
17·5	1·033	33·57	56	1·865	60·05	350	4·663	150·1
18	1·057	34·05	58	1·898	61·12	375	4·826	155·4
18·5	1·072	34·52	60	1·930	62·16	400	4·984	160·5
19	1·086	34·98	62	1·962	63·19	425	5·138	165·4
19·5	1·101	35·44	64	1·994	64·20	450	5·287	170·2
20	1·115	35·89	66	2·025	65·20	475	5·432	174·9
21	1·141	36·77	68	2·055	66·18	500	5·573	179·9
22	1·167	37·64	70	2·085	67·14	550	5·845	188·2
23	1·194	38·49	72	2·115	68·09	600	6·105	196·6
24	1·221	39·31	74	2·144	69·03	650	6·354	204·6
25	1·246	40·12	76	2·173	69·96	700	6·594	212·3
26	1·271	40·92	78	2·201	70·87	750	6·825	219·8
27	1·295	41·70	80	2·229	71·78	800	7·049	226·9
28	1·319	42·47	82	2·257	72·67	850	7·266	234·0
29	1·342	43·22	84	2·284	73·55	900	7·477	240·7
30	1·365	43·95	86	2·311	74·42	950	7·681	247·3
31	1·388	44·68	88	2·338	75·28	1000	7·881	253·8
32	1·410	45·39	90	2·364	76·13	1500	9·652	310·8
33	1·432	46·10	92	2·390	76·97	2000	11·15	358·9
34	1·453	46·79	94	2·416	77·81	2500	12·46	401·2
35	1·474	47·47	96	2·442	78·63	3000	13·65	439·5
36	1·495	48·15	98	2·467	79·45	3500	14·74	474·7
37	1·516	48·81	100	2·492	80·25	4000	15·76	507·5
38	1·536	49·47	110	2·614	84·17	4500	16·72	538·3
39	1·556	50·11	120	2·730	87·91	5000	17·62	567·4
40	1·576	50·75	130	2·842	91·50	7500	21·58	695·0
41	1·596	51·38	140	2·949	94·95	10000	24·92	802·5
42	1·615	52·01	150	3·032	98·28			

during which an accelerating force is applied to the body, supposing that the body is started from a state of rest; v the final velocity acquired; s the space in feet traversed by the body during the time—the equivalent of the height in the rules for gravity; f the accelerating force in pounds; w the weight of the body in pounds. The velocity acquired is directly as the accelerating force, and inversely as the weight of the body.

Rules for Accelerated Motion.

RULE 1.—To find *the final velocity*, given the weight, the force, and the space. Multiply the force by the space, and divide by the weight; find the square root of the quotient, and multiply by 8. Or,

$$v=8\sqrt{\frac{fs}{w}} \quad . \quad . \quad . \quad . \quad . \quad (41)$$

RULE 2.—To find *the final velocity*, given the weight, the force, and the time. Multiply the force by the time, and by 32·2, and divide by the weight. Or,

$$v=\frac{32{\cdot}2\,ft}{w} \quad . \quad . \quad . \quad . \quad . \quad (42)$$

RULE 3.—To find *the force*, given the weight, the final velocity, and the space. Multiply the weight by the square of the final velocity, and divide by the space, and by 64·4. Or,

$$f=\frac{wv^2}{64{\cdot}4s} \quad . \quad . \quad . \quad . \quad . \quad (43)$$

RULE 4.—To find *the force*, given the weight, the final velocity, and the time. Multiply the weight by the velocity, and divide by the time, and by 32·2. Or,

$$f=\frac{wv}{32{\cdot}2t} \quad . \quad . \quad . \quad . \quad . \quad (44)$$

RULE 5.—To find *the weight*, given the force, the velocity, and the space. Multiply the force by the space, and by 64·4, and divide by the square of the velocity. Or,

$$w=\frac{64{\cdot}4fs}{v^2} \quad . \quad . \quad . \quad . \quad . \quad (45)$$

RULE 6.—To find *the space*, given the weight, the final velocity, and the force. Multiply the weight by the square of the velocity, and divide by the force, and by 64·4. Or,

$$s=\frac{wv^2}{64{\cdot}4f} \quad . \quad . \quad . \quad . \quad . \quad (46)$$

Rule 7.—To find *the space*, given the weight, the force, and the time. Multiply the force by the square of the time, and by 16·1, and divide by the weight. Or,

$$s=\frac{16{\cdot}1ft^2}{w} \qquad (47)$$

Rule 8.—To find *the space*, given the velocity and the time. Multiply the velocity by the time, and divide by 2.

$$s=\frac{vt}{2} \qquad (48)$$

Rule 9.—To find *the time*, given the weight, the force, and the final velocity. Multiply the weight by the velocity, and divide by the force, and by 32·2. Or,

$$t=\frac{wv}{32{\cdot}2f} \qquad (49)$$

Rule 10.—To find *the time*, given the weight, the force, and the space. Multiply the weight by the space, and divide by the force; find the square root of the quotient, and divide by 4. Or,

$$t=\tfrac{1}{4}\sqrt{\frac{ws}{f}} \qquad (50)$$

The foregoing formulæ are available for calculating questions of retarded motion; v being the initial velocity, f the retarding force, w the weight of the body, s the space in which the motion is reduced to nothing, and t the time of retardation.

Rule 11.—To find the *accelerating or retarding force* in a body which is in motion at the beginning and end of the space traversed, when the space is given, and also the velocities at the beginning and the end of the space. Divide the difference of the squares of the velocities by the space and by 64·4, and multiply by the weight. The product is the accelerating or retarding force, according as the less or the greater velocity is the initial velocity. Or,

$$f=w\left(\frac{v^2-v_1^{\,2}}{64{\cdot}4s}\right) \qquad (51)$$

Note.—When the weight and the force are in simple relation to each other, expressible by a simple fraction, the terms of the fraction may be substituted for w and f in the formulæ (41), (42), (46), (47), (49), (50), and calculation simplified.

Descent of Bodies on Inclined Planes.

The descent of a body on an inclined plane by the gravitation of the body, is a case of an accelerating force less th that of gravity on a vertically falling body; to be solved by the aid of the general formulas for accelerating forces. The accelerating force of gravitation on an inclined plane is to the direct force of gravity in the ratio of the height of the plane to the length of the plane; and it is therefore inversely proportional to the length of the plane, when the height is the same. The accelerating force v is determined by multiplying the weight of the descending body by the height of the plane, and dividing the product by the length of the plane. For instance, a body weighing 100 lbs., on an inclined plane 1000 feet long and 20 feet high, is controlled by an accelerating force of $(100 \times \frac{20}{1000} = 100 \times \frac{1}{50} =)$ 2 pounds. But, inasmuch as the accelerating force acts through a space, or length of incline, proportionally longer as the force is less, the time of descent is also proportionally longer, and the final velocity acquired at the foot of the incline is equal to that due to the vertical height for a falling body. These relations are deduced without allowance for external resistances.

To adjust formula (50) for finding the time of free descent of an inclined plane:—w and f being in proportion to l, the length of the plane, and h the height of it, these may be substituted for w and f in the formula, and $t = \frac{1}{4}\sqrt{\frac{ws}{f}}$ becomes $t = \frac{1}{4}\sqrt{\frac{ls}{h}}$; and, as $s = l$, $t = \frac{1}{4}\sqrt{\frac{l^2}{h}}$; or, finally,

$$t = \frac{l}{4\sqrt{h}} \quad . \quad . \quad . \quad . \quad . \quad . \quad (52)$$

RULE 1.—To find the *time* of descent, given the length and the height of the inclined plane. Divide the length of the plane by 4 times the square root of the height of the plane.

Central Forces.

When a body revolves about an axis or centre, it is subject to centrifugal force, by which it is urged to fly from the centre; and to centripetal force, the reactive force by which the centrifugal force is balanced, and by which the body is constrained to move in a circular path. These are known as central forces.

Central force varies as the square of the speed of revolution, whether in terms of the linear or circumferential velocity, or of the angular speed in revolutions per unit of time.

It varies as the radius of the circle of revolution.

It varies as the mass or weight of the revolving body.

Let :—

w = the weight of the revolving body, in pounds.

$\frac{w}{g}=\frac{w}{32\cdot 2}$ = the mass of the body ; g representing gravity.

v = the linear or circumferential velocity in feet per second.

v_1 = the angular velocity, or revolutions per second.

f = the centrifugal force in pounds.

r = the radius of gyration of the revolving body, in feet.

Rules for Centrifugal Force in terms of Circumferential Velocity.

RULE 1.—To find the *centrifugal force*, given the weight, the linear velocity, and the radius of gyration. Multiply the weight by the square of the linear velocity, and divide by 32·2 times the radius of gyration. Or,

$$f=\frac{wv^2}{32\cdot 2r} \quad . \quad . \quad . \quad . \quad . \quad . \quad (53)$$

RULE 2.—To find the *linear velocity*, when the weight, the centrifugal force, and the radius of gyration are given. Multiply the centrifugal force by the radius of gyration, and by 32·2, and divide by the weight ; take the square root of the quotient. Or,

$$v=\sqrt{\frac{32\cdot 2fr}{w}} \quad . \quad . \quad . \quad . \quad . \quad . \quad (54)$$

RULE 3.—To find the *weight*, when the centrifugal force, the linear velocity, and the radius of gyration are given. Multiply the centrifugal force by the radius of gyration, and by 32·2, and divide by the square of the velocity. Or,

$$w=\frac{32\cdot 2fr}{v^2} \quad . \quad . \quad . \quad . \quad . \quad (55)$$

RULE 4.—To find the *radius of gyration*, when the weight, the linear velocity, and the centrifugal force are given. Multiply the weight by the square of the velocity, and divide by the centrifugal force, and by 32·2. Or,

$$r=\frac{wv^2}{32\cdot 2f} \quad . \quad . \quad . \quad . \quad . \quad . \quad (56)$$

Rules for Centrifugal Force in terms of Angular Velocity.

The linear velocity v is equal to the angular velocity, v_1, multiplied by the radius of gyration and by 6·2832 (twice 3·1416). Or,

$$v=6\cdot 2832v_1r \quad . \quad . \quad . \quad . \quad . \quad . \quad (57)$$

By substitution, in equation (53), and reduction, formula (58) is produced.

RULE 5.—To find *the centrifugal force*, when the weight, the angular velocity, and the radius of gyration are given. Multiply the weight by the square of the angular velocity and by the radius of gyration, and by 1·226. Or,

$$f = 1{\cdot}226 w v_1^2 r \quad . \quad . \quad . \quad . \quad . \quad (58)$$

RULE 6.—To find *the angular velocity*, when the weight, the centrifugal force, and the radius of gyration are given. Multiply the weight by the radius of gyration, and by 1·226; divide the centrifugal force by the product so produced; and take the square root of the quotient. Or,

$$v_1 = \sqrt{\frac{f}{1{\cdot}226 w r}} \quad . \quad . \quad . \quad . \quad . \quad (59)$$

RULE 7.—To find *the weight*, when the centrifugal force, the angular velocity, and the radius of gyration are given. Multiply the square of the angular velocity by the radius of gyration, and by 1·226; divide the centrifugal by the product. Or,

$$w = \frac{f}{1{\cdot}226 v_1^2 r} \quad . \quad . \quad . \quad . \quad . \quad (60)$$

RULE 8.—To find *the radius of gyration*, when the weight, the angular velocity, and the centrifugal force are given. Multiply the weight by the square of the angular velocity, and by 1·226; and divide the centrifugal force by the product. Or,

$$r = \frac{f}{1{\cdot}226 w v_1^2} \quad . \quad . \quad . \quad . \quad . \quad (61)$$

Work.

The English unit of work is one foot-pound.

The French unit is one kilogrammetre.

One kilogrammetre is equal to 7·233 foot-pounds.

One foot-pound is equal to ·1382 kilogrammetre.

One horse-power is equal to work done at the rate of 33,000 pounds lifted one foot high, or 33,000 foot-pounds, per minute: or to 550 foot-pounds per second; or to (33,000 × 60 =)1,900,000 foot-pounds per hour—nearly 2 millions.

One cheval-vapeur, or cheval (French horse-power) is equal to 75 kilogrammetres, or 542·5 foot-pounds, per second.

One cheval is equal to ·9863 horse-power.

One horse-power is equal to 1·0139 chevaux.

One kilogramme per cheval is equal to 2·235 pounds per horse-power.

One pound per horse-power is equal to ·447 kilogramme per cheval.

If the work of a horse-power, expressed in foot-pounds, be divided by 772, the quotient is the equivalent expression of horse-power in heat-units; or, $(33{,}000 \div 772 =)42\frac{3}{4}$ heat-units per minute.

The work, known also as *vis viva*, done by gravity on a falling body is equal to the weight of the body multiplied by the height of the fall: the evidence of which is the velocity of motion acquired by the body.

The quantity of work stored in a body in motion is equal to the work which would be accumulated in it by gravity in falling from such a height as would suffice to generate the same velocity of motion. Consequently, the formulas proper for the action of gravity are applicable for calculations affecting bodies in motion, and the product of the height due to the velocity by the weight of the body, is expressive of the work stored in the body.

The height due to the velocity is equal to the square of the velocity divided by 64·4, according to formula (33), page 431, and as tabulated, page 434, and

$$U = \frac{wv^2}{64{\cdot}4} \quad . \quad . \quad . \quad . \quad . \quad (62)$$

$$\text{or } U = w \times h \quad . \quad . \quad . \quad . \quad . \quad (63)$$

U = the work accumulated in the body, in foot-pounds.
w = the weight of the body in pounds.
v = the velocity of the body in feet per second.
v_1 = the angular velocity of a revolving body, in revolutions per second.
v_{11} = the same in revolutions per minute.
h = the height due to the velocity, in feet.
r = the radius of gyration, in feet.

RULE 1.—To find the *work stored* in a moving body, given the weight of the body and the velocity. Multiply the weight of the body by the square of the velocity, and divide by 64·4.

RULE 2.—To find the *work stored* in a moving body, given the weight of the body, and the height due to the velocity. Multiply the weight by the height.

The work stored in a revolving body is calculated by either of the above rules, when linear velocity is given. But when the angular velocity is given, the equivalent to the linear velocity is found by substituting the expression $6{\cdot}2832 r_1 v_1$

already deduced, page 439, for v in the formula (1), and reducing, thus :—

$$U = \cdot 613\, w v_1^2 r^2 \quad . \quad . \quad . \quad . \quad . \quad (64)$$

Rule 3.—To find the *work stored* in a revolving body, given the weight of the body, the angular velocity in revolutions per second, and the radius of gyration. Multiply the weight by the square of the angular volocity, and by the square of the radius of gyration, and by ·613.

When the angular velocity is given as the number of revolutions per minute, it is either to be divided by 60, before being brought into calculation, in accordance with the foregoing rule; or the expression $\frac{6 \cdot 2832\, v_1 r}{60}$ is to be substituted for v in the formula (1), when the expression becomes,

$$U = \frac{w}{64 \cdot 4} \times \left(\frac{6 \cdot 2832 v_{11} r}{60} \right)^2, \text{ or reducing :—}$$

$$U = \cdot 00017 w v_{11}^2 r^2 \quad . \quad . \quad . \quad . \quad . \quad (65)$$

$$\text{or } U = \frac{w v_{11}^2 r^2}{5868} \quad . \quad . \quad . \quad . \quad . \quad . \quad (66)$$

Rule 4.—To find the *work stored* in a revolving body, given the weight of the body, the angular velocity in revolutions per minute, and the radius of gyration. Multiply the weight by the square of the angular velocity, by the square of the radius of gyration, and by ·00017.

Rule 5.—For the same purpose, proceed as in rule 4, except to divide by 5868, instead of multiplying by ·00017.

The work done by percussive force is simply measurable by the product of the weight of the colliding mass, and the height due to the velocity of the moment of impact plus the space moved through by the colliding mass after striking. Supposing that the blow be delivered fairly, without causing vibratory action, the work of resistance is equal to the work of impact. In the driving of a wedge, for instance, the product of the advance of the wedge by the resistance, cohesive and frictional, is equal to the work stored in the striking body. In the driving of a pile, similarly, the product of the frictional resistance by the advance of the pile under the blow of a ram is equal to the work stored in the ram. Of course, the stored work may to some extent be dissipated in vibratory action, leaving but a part of the stored work for useful performance.

MILL GEARING, SHAFTING, &c.

Driving Belts.

The ultimate tensile strength of leather belts of good quality, about ¼ inch thick, is about 1,000 pounds per inch of width. That of ordinary belts is about 750 pounds per inch of width. At laced junctions of ends of belts, the ultimate tensile strength is only about 200 pounds per inch of width. Taking Briggs and Towne's data, and assuming one-third of 200 pounds, or 66⅔ pounds per inch wide, as the maximum working stress, the Table 232 gives the driving power of leather belts.

TABLE 232.—DRIVING POWER OF LEATHER BELTS, ·22 INCH THICK.
(Clark's *Manual.*)

Arcs of Contact.	Maximum Working-Stress transmitted per Inch Wide.	Power transmitted per Inch Wide.			Sum of the Tensions on both Sides of a Belt per Inch Wide.	Resultant Pressure on the Journals per Inch Width of Belt.
		At One Foot per Second, Velocity of Belt.	Per Foot of Diameter of Pulley and per Turn per Minute.			
Degrees.	Pounds.	H. P.	H. P.	Ft.-lbs.	Pounds.	Pounds.
90	32·33	·059	·00308	102	101·00	71·42
100	34·80	·063	·00331	109	98·53	75·47
110	37·07	·067	·00353	116	96·26	78·85
120	39·18	·071	·00373	123	94·15	81·53
135	42·06	·076	·00400	132	91·27	84·32
150	44·64	·081	·00425	140	88·69	85·67
180	49·01	·089	·00467	154	84·32	84·32
210	52·52	·095	·00500	165	80·81	78·05
240	53·33	·100	·00527	174	78·00	67·59
270	57·58	·105	·00548	181	75·75	53·56

The Table 233 of the horse-power of belting is calculated for pulleys of nearly equal diameters, or which are well apart, allowing the belt to lap half round the smaller pulley.

Where the arc of contact is sensibly less than a semicircle, the tabular power transmitted is to be reduced in the same proportion.

The Table 233 is based on an allowance of 800 feet per minute travel of belting 1 inch width per horse-power; equivalent to about 41 pounds tension per 1 inch width of belt.

TABLE 233.—DRIVING POWER OF LEATHER BELTS. (F. A. Halsey.)

Diameter of Pulley.	Revolutions of the Pulley per Minute.											
	50	60	70	80	90	100	125	150	175	200	250	300
	Horse-Power Transmitted by each Inch Wide of Single Belt.											
Inches.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.
12	·20	·24	·28	·32	·35	·39	·49	·59	·69	·79	·98	1·18
14	·23	·28	·32	·37	·41	·46	·57	·69	·80	·92	1·14	1·38
16	·26	·32	·37	·42	·47	·53	·66	·79	·92	1·05	1·31	1·58
18	·30	·35	·41	·47	·53	·59	·74	·89	1·04	1·18	1·48	1·77
20	·33	·39	·46	·52	·59	·65	·82	·98	1·14	1·31	1·64	1·96
24	·39	·47	·55	·63	·71	·79	·98	1·18	1·38	1·58	1·97	2·36
28	·46	·55	·64	·73	·83	·92	1·15	1·38	1·61	1·84	2·29	2·75
32	·52	·63	·73	·84	·94	1·05	1·31	1·57	1·84	2·10	2·63	3·15
36	·59	·71	·83	·95	1·06	1·18	1·48	1·77	2·06	2·36	2·96	3·55
40	·65	·79	·92	1·04	1·18	1·31	1·64	1·96	2·29	2·62	3·27	3·94
44	·72	·87	1·01	1·15	1·30	1·45	1·80	2·16	2·53	2·89	3·60	4·34
48	·79	·94	1·10	1·26	1·42	1·57	1·96	2·36	2·75	3·15	3·93	4·72
54	·89	1·06	1·24	1·42	1·59	1·77	2·22	2·66	3·10	3·55	4·43	5·31
60	·98	1·18	1·38	1·57	1·77	1·96	2·46	2·95	3·44	3·93	4·91	5·90
66	1·08	1·30	1·52	1·73	1·95	2·17	2·71	3·25	3·79	4·33	5·41	6·50
72	1·18	1·42	1·65	1·89	2·13	2·36	2·95	3·54	4·13	4·72	5·90	7·10
78	1·28	1·53	1·79	2·04	2·30	2·56	3·20	3·84	4·48	5·11	6·40	7·68
84	1·38	1·65	1·93	2·21	2·48	2·75	3·44	4·13	4·81	5·51	6·89	8·28
90	1·48	1·77	2·06	2·36	2·66	2·96	3·68	4·43	5·18	5·90	7·38	8·85
96	1·57	1·89	2·21	2·53	2·84	3·15	3·95	4·73	5·51	6·31	7·89	9·45

Rules for Speed of Belt-Pulleys.

To find the diameter of the driving pulley. Multiply the diameter of the driven pulley by the speed, or the number of revolutions it is to make per minute, and divide the product by the revolutions of the driving pulley per minute. The quotient is the diameter of the driver.

To find the diameter of the driven pulley. Multiply the diameter of the driving pulley by its speed, and divide the product by the speed of the driven pulley. The quotient is the diameter of the driven pulley.

To find the speed of the driven pulley. Multiply the diameter of the driving pulley by its speed; and divide the product by the diameter of the driven pulley. The quotient is the speed of the driven pulley.

Weight of Belt-Pulleys (Clark's *Manual*).

Pulleys of from 1 foot to 4 feet in diameter, turned and finished; Midland district :—

$$W = 7d - 1{\cdot}75 \quad . \quad . \quad . \quad . \qquad (1)$$

W = weight of pulley in pounds per inch wide.
d = diameter, in feet.

This formula is probably applicable for pulleys of from 10 inches to 10 feet in diameter.

Pulleys of from 1 foot to 7 feet in diameter, turned and finished; London district :—

Not exceeding 2 feet in diameter $W = 3d^2 - {\cdot}625d + 2{\cdot}75$ (2)
2 feet and upwards ,, $W = 11{\cdot}625d - 9{\cdot}25$ (3)

TABLE 234.—WEIGHT OF ROUND WROUGHT-IRON SHAFTING.

Diameter of Shaft.	Weight per Lineal Foot.	Diameter of Shaft.	Weight per Lineal Foot.	Diameter of Shaft.	Weight per Lineal Foot.	Diameter of Shaft.	Weight per Lineal Foot.
Inches.	Pounds.	Inches.	Pounds.	Inches.	Pounds.	Inches.	Pounds.
1	2·62	2¾	19·8	5½	79·2	11	317
1¼	4·09	3	23·6	5¾	86·6	12	377
1½	5·89	3¼	27·7	6	94·2	13	398
1⅝	6·91	3½	32·1	6½	111	14	462
1¾	8·02	3¾	33·5	7	128	15	530
1⅞	9·20	4	41·9	7½	147	16	670
2	10·5	4¼	47·3	8	168	17	759
2⅛	11·8	4½	53·0	8½	189	18	848
2¼	13·3	4¾	59·1	9	212	19	945
2⅜	14·8	5	65·5	9½	236	20	1040
2½	16·4	5¼	72·2	10	262		

Note.—To find the weight of steel shafting, multiply the tabular values by 1·02.

TABLE 235.—HORSE-POWER OF SHAFTING.

Diameter of the Shaft.	Speed or Revolutions per Minute.											
	50	60	70	80	90	100	125	150	175	200	250	300
	Horse-Power transmitted by the Shaft.											
Inches.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.
1	·40	·48	·56	·64	·72	·80	1·00	1·20	1·40	1·60	2·00	2·40
1¼	·78	·94	1·09	1·25	1·40	1·56	1·95	2·34	2·73	3·12	3·90	4·69
1½	1·35	1·62	1·89	2·16	2·43	2·70	2·87	4·05	4·72	5·40	6·75	8·10
1⅝	1·72	2·06	2·41	2·75	3·10	3·44	4·30	5·16	6·02	6·88	8·60	10·32
1¾	2·14	2·57	3·00	3·43	3·86	4·29	5·36	6·43	7·50	8·58	10·72	12·86
1⅞	2·64	3·17	3·70	4·23	4·76	5·27	6·59	7·91	9·23	10·55	13·19	15·82
2	3·20	3·84	4·48	5·12	5·76	6·40	8·00	9·60	11·20	12·80	16·00	19·20
2⅛	3·83	4·60	5·37	6·14	6·91	7·67	9·58	11·50	13·42	15·33	19·16	23·00
2¼	4·55	5·46	6·37	7·28	8·19	9·11	11·39	13·66	15·94	18·22	22·77	27·33
2⅜	5·36	6·43	7·50	8·57	9·64	10·72	13·40	16·08	18·76	21·44	26·80	32·16
2½	6·25	7·50	8·75	10·00	11·25	12·50	15·62	18·75	21·87	25·00	31·25	37·50
2¾	8·33	10·00	11·67	13·34	15·01	16·67	20·83	25·00	29·17	33·33	41·66	50·00
3	10·80	12·96	15·12	17·28	19·44	21·60	27·00	32·40	57·80	43·20	54·00	64·80
3¼	13·73	16·48	19·23	21·98	24·73	27·46	34·33	41·19	48·05	54·93	68·66	82·39
3½	17·15	20·58	24·01	27·44	30·87	34·30	42·88	51·45	60·03	68·60	85·75	102·90
3¾	21·09	25·31	29·53	33·75	37·97	42·17	52·71	63·25	73·79	84·33	105·42	126·50
4	25·60	30·72	35·84	40·96	46·08	51·20	64·00	76·80	89·60	102·40	128·00	153·60
4¼	30·71	36·85	42·99	49·13	55·27	61·41	76·76	92·12	107·47	122·82	153·53	184·23
4½	36·45	43·74	51·03	58·32	65·61	72·90	91·13	109·35	127·58	145·80	182·25	218·70
4¾	42·87	51·44	60·01	68·58	77·15	85·74	107·17	128·61	150·04	171·47	214·34	257·21
5	50·00	60·00	70·00	80·00	90·00	100·00	125·00	150·00	175·00	200·00	250·00	300·00
5¼	57·88	69·45	81·02	92·59	104·16	115·74	144·68	173·60	202·54	231·47	289·35	347·21
5½	66·55	79·86	93·17	106·48	119·79	133·12	166·39	199·68	233·96	266·24	332·79	399·36
5¾	76·04	91·25	106·46	121·67	136·88	152·08	190·10	228·12	266·14	304·16	380·20	456·24
6	86·40	103·68	120·96	138·24	155·52	172·80	216·00	259·20	302·40	345·60	432·00	518·40

Horse-Power of Shafting.

The Table 235 is calculated by means of the formula :—

$$HP = \frac{d^3 \times t}{125} \quad . \quad . \quad . \quad . \quad (4)$$

HP = horse-power.
d = diameter of shaft in inches.
t = speed in turns per minute.

Toothed Wheels.

The Table 236 of the driving power of toothed wheels is based on the formula :—

$$HP = \frac{p \times f \times d \times t}{850} \quad . \quad . \quad . \quad . \quad (5)$$

HP = horse-power transmitted.
p = pitch in inches.
f = width of face of teeth, in inches.
d = diameter of wheel, in inches.
t = turns per minute.

By this formula a pressure of about 150 pounds is exerted on the teeth of a wheel of 1 inch pitch and 1 inch face ; with a proportionate stress on teeth of other pitches.

Weight of Cast-Iron Spur-Wheels of from 1 inch to 6 inches Pitch (Clark's *Manual*).

Applicable for diameters up to 20 feet.

$$W = (\cdot 05 + \cdot 08p)d \times (1 + \cdot 10d) \quad . \quad . \quad (6)$$

W = weight of wheel per inch of face, in cwts.
d = diameter in feet.
p = pitch in inches.

Weight of Cast-Iron Spur-Wheels of Pitches less than 1 inch.

Pitch.

$$\left.\begin{matrix}\frac{7}{8}\\ \frac{3}{4}\end{matrix}\right\} \; W = \cdot 0935d + \cdot 0235d^2 \quad . \quad . \quad . \quad . \quad (7)$$

$$\tfrac{1}{2} \quad W = \cdot 069d + \cdot 0345d^2 \quad . \quad . \quad . \quad . \quad . \quad (8)$$

$$\tfrac{3}{8} \quad W = \cdot 080d + \cdot 0530d^2 \quad . \quad . \quad . \quad . \quad (9)$$

Mortise Wheels are of the same weight as spur-wheels of equal diameter.

Bevil Wheels and *Mitre Wheels* weigh from two-thirds to three-fourths of spur-wheels for the larger diameters, to about seven-eighths for the smaller diameters.

TABLE 236.—HORSE-POWER OF TOOTHED WHEELS. (F. A. Halsey.)

Pitch of Teeth.	Diameter of Wheel in Inches.																	
	6	9	12	15	18	21	24	30	36	42	48	54	60	72	84	96	108	120
	Horse-Power per Revolution per Minute and per Inch of Face.																	
Inches.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.
1	·007	·011	·014	·018	·021	·025	·028	·035	·042	·049	·056	·064	·071	·085	·099	·113	·127	·141
1¼	·009	·013	·018	·022	·026	·031	·035	·044	·053	·062	·071	·079	·088	·106	·124	·141	·159	·176
1½	·011	·016	·021	·026	·032	·037	·042	·053	·064	·074	·084	·095	·106	·127	·148	·169	·190	·212
1¾	...	·019	·025	·031	·037	·043	·049	·062	·074	·086	·099	·111	·123	·148	·173	·198	·223	·247
2	...	·021	·028	·035	·042	·049	·056	·071	·085	·097	·113	·127	·141	·169	·198	·226	·255	·282
2¼	...	...	·032	·040	·048	·056	·063	·079	·095	·111	·127	·143	·158	·191	·222	·255	·286	·318
2½	...	...	·035	·044	·053	·062	·071	·088	·106	·123	·141	·159	·176	·212	·246	·283	·318	·353
2¾	...	...	...	·049	·058	·068	·078	·097	·117	·136	·155	·175	·194	·233	·272	·311	·349	·388
3	...	...	...	·053	·064	·074	·085	·106	·127	·148	·169	·191	·212	·254	·296	·338	·381	·423
3¼	...	...	...	...	·069	·080	·092	·115	·138	·160	·183	·206	·229	·275	·321	·367	·413	·459
3½	...	...	...	...	·074	·086	·098	·123	·148	·173	·197	·222	·246	·296	·345	·395	·443	·493
3¾	...	...	...	...	·079	·093	·106	·132	·159	·185	·212	·238	·264	·318	·370	·423	·477	·529
4	...	...	...	...	...	·098	·113	·141	·169	·197	·225	·254	·282	·338	·395	·451	·508	·564
4½	...	...	...	...	...	·111	·127	·159	·191	·223	·254	·286	·317	·381	·443	·510	·570	·633
5	...	...	...	...	...	...	·141	·176	·212	·247	·282	·318	·353	·423	·494	·565	·635	·705
6	...	...	...	...	...	...	·169	·211	·256	·296	·338	·381	·423	·509	·592	·679	·761	·846

TABLE 237.—TRANSMISSION OF POWER.
(Harpers.)

Toothed Wheels (Double-flanged Wheel one-third more powerful).				Steel Shafting.		Single Belting.		One Rope.	
Breadth of Teeth.	Pitch of Teeth.	Power that can be transmitted per 100 Feet of Circumferential Velocity per Minute.		Diameter.	Power that can be transmitted per 10 Revolutions per Minute.	Breadth.	Power that can be transmitted for every 100 Feet of Velocity per Minute.	Diameter.	Power that can be transmitted for every 100 Feet of Velocity per Minute.
		Spur.	Bevel.						
Inches.	Inches.	H. P.	H. P.	Inches.	H. P.	Inches.	H. P.	Inches.	H. P.
2	1	$\frac{3}{8}$	$\frac{1}{4}$	$1\frac{1}{2}$	$\frac{1}{2}$	3	$\frac{3}{8}$	$\frac{3}{4}$	$\frac{1}{5}$
3	$1\frac{1}{4}$	$\frac{5}{8}$	$\frac{1}{2}$	2	$1\frac{1}{8}$	4	$\frac{1}{2}$	1	$\frac{1}{4}$
4	$1\frac{1}{2}$	$1\frac{1}{8}$	$\frac{7}{8}$	$2\frac{1}{2}$	$2\frac{1}{4}$	5	$\frac{5}{8}$	$1\frac{1}{4}$	$\frac{2}{5}$
5	$1\frac{3}{4}$	2	$1\frac{1}{2}$	3	$3\frac{7}{8}$	6	$\frac{3}{4}$	$1\frac{1}{2}$	$\frac{3}{5}$
6	2	$3\frac{1}{8}$	$2\frac{3}{8}$	$3\frac{1}{2}$	6	7	$\frac{7}{8}$	$1\frac{3}{4}$	$\frac{3}{4}$
7	$2\frac{1}{4}$	$4\frac{1}{2}$	$3\frac{1}{2}$	4	9	8	1	2	1
8	$2\frac{1}{2}$	$6\frac{1}{4}$	$4\frac{7}{8}$	$4\frac{1}{2}$	13	9	$1\frac{1}{8}$	...	...
9	$2\frac{3}{4}$	$8\frac{1}{2}$	$6\frac{1}{2}$	5	18	10	$1\frac{1}{4}$	...	...
10	3	$11\frac{1}{4}$	$8\frac{1}{2}$	$5\frac{1}{2}$	24	12	$1\frac{1}{2}$	...	...
11	$3\frac{1}{4}$	$14\frac{3}{4}$	11	6	31	15	$1\frac{7}{8}$	...	...
12	$3\frac{1}{2}$	19	14	...	...	18	$2\frac{1}{4}$	...	...

Friction-Wheel Gearing.

The grooves of friction-wheels are of **V** shape, forming the angle 50 degrees; usually at ⅜-inch pitch. Compared with leather belts, frictional gearing, worked under a pressure equal to the tension of the belts, has been proved to have greater adhesive force: 30 per cent. more, in one case.

Transmission of Power (J. Bagshaw & Sons).

BELTING.—*To find the horse-power which can be transmitted by single leather belts.*—Multiply the breadth of belt in inches by 70, and by the speed of belt in feet per minute; and divide by 33,000. The quotient is the horse-power.

Double belts transmit 1½ times as much power as single belts.

To find the width of single belt for transmitting a given horse-power.—Multiply the horse-power by 33,000, and divide by 70 times the speed of the belt in feet per minute. The quotient is the width of belt in inches.

These rules are sufficiently approximate where there is no great degree of inequality in the diameters of the pulleys.

SHAFTING.—*To find the horse-power which can be transmitted by a wrought iron shaft.*—Multiply the cube of the diameter of the shaft in inches by the number of revolutions per minute, and divide by 80. The quotient is the horse-power.

To find the diameter of a wrought iron shaft required to transmit a given horse-power.—Multiply the horse-power by 80, and divide by the number of revolutions per minute. The cube root of the quotient is the diameter in inches.

ROPES.—*To find the horse-power that can be transmitted by ropes.*—Mulitiply the sectional area of one rope in square inches by 100 times the speed of the rope in feet per minute, and divide by 33,000. The quotient is the horse-power for one rope.

Or, multiply the sectional area of one rope by the speed, and divide by 330.

TOOTHED WHEELS.—*To find the horse-power that can be transmitted by toothed wheels.*—Multiply the velocity of the pitch-line in feet per second by the breadth of the teeth in inches, and by the square of the pitch in inches, and divide by 15. The quotient is the horse-power.

For bevel wheels, the mean diameter and mean pitch are to be taken.

TRANSMISSION OF MOTIVE POWER TO GREAT DISTANCES.

Transmission by Hemp Ropes.

For the driving gear of large steam engines, hemp ropes are much employed to take off the power from the circumference of the fly-wheel, which is grooved. The tension on the ropes is usually about 100lb. per square inch of section. The usual speed is from 4,500 to 5,500 feet per minute.

TABLE 238.—HORSE-POWER BY MANILLA ROPES. (Leavitt.)

Speed of Rope, in Feet per Minute.	1000	1500	2000	2500	3000	3500	4000	4500	5000
Diameter of Rope.	Horse-Power.								
Inches.									
¾	1 8/1	2¾	3½	4½	5½	6½	7	8¼	9
1	3½	4⅞	6½	8	10	11	13	15	16
1¼	5⅛	7½	10¼	13	15	18	20	23	26
1½	7½	11	15	18	22	26	30	34	37
1¾	10	15	20	25	30	35	40	45	50
2	13	19½	26	33	39	46	52	59	65

Transmission of Motive Power by Wire-Rope.

In one case, power was transmitted from a water-wheel through a horizontal distance of 400 feet by means of an iron wire-rope ·433 inch in diameter, which passed over two grooved cast-iron pulleys 6·56 feet in diameter, lined in the groove with compressed and tarred leather. The rope was formed of a central ply of Bologna hemp, tarred, around which were twisted six strands, each of eight iron wires, $\frac{1}{25}$ inch thick, on a core of tarred hemp. The speed was brought up by toothed gearing in two stages, so that the motor pulley made 19·04 turns for one of the water-wheel. For a speed of 96 turns per minute of the first intermediate shaft, the motor-pulley makes 145·85 turns, and the speed of its periphery is 50 feet per second, or 3000 feet per minute. At this speed, the loss by frictional resistance of the gearing and rope was 6·82 per cent.

Transmission of Motive Power by Compressed Air.

The Paris Compressed Air Company supply air compressed by steam power, of 5 atmospheres pressure, to secondary engines of two types :—rotary engines for powers up to about

1 horse-power; and larger sized motors, up to double-cylinder engines having 12-inch cylinders with 14-inch stroke,—ordinary steam-engines employed for air. The secondary motor, when indicating 9·9 horse-power, and making 125 revolutions, according to Professor Kennedy, uses 890 cubic feet of air per indicator horse-power per hour. A small motor four miles distant from the central station, can indicate, in round numbers, 10 horse-power for 20 horse-power at the station, allowing for the value of the coke used in heating the air, or for 25 horse-power, if the air be not heated at all: making in the second instance an efficiency of 40 per cent.

Transmission of Domestic Motive Power by Atmospheric Exhaustion.

The distribution of power in dwelling-houses in Paris is effected by means of the exhaustion of air from a system of pipes, laid in the sewers for the most part, from which the power is supplied in small quantities to work the tools or machines employed in small industries. A vacuum, averaging 67 per cent. or 20 inches of mercury,—occasionally reaching to 75 per cent. or 22½ inches—is maintained in a reservoir, 49 inches in diameter, 11½ feet in length, serving to regulate the pressure in the service pipes. These are 10 inches and 8 inches in diameter, from the pumping station to the sewer, and 8 inches and 4 inches in the sewer or trench. The conduits do not exceed from 1 mile to 1¼ miles in length. The secondary motors are of the trunk type: supplying powers of from $\frac{1}{25}$th to 1 horse-power.

The air-cylinder utilises 93 per cent. of the engine-power transmitted. Of this the exhaust motors utilise a maximum of 60 per cent.; the loss of head in the main is 5 per cent.; lastly, the air yields only 85 per cent. of its total capacity for work. The resulting coefficient is 45 per cent.; and the actual work of 1 cubic foot of air is 1246 foot-pounds.

Transmission of Motive Power by Electricity.

This is easily effected, where the power does not exceed 30 horse-power, nor the distance 1¼ miles. In experiments by M. Fontaine, the dynamos made 1,200 revolutions per minute. The power delivered at the periphery of the fly-wheel of the steam engine was 95 horse-power; at the break, 50 horse-power; resistance of intermediate conductors (⅕ inch copper wire, 77½ miles long), 100 ohms; 6,700 volts at origin of conducting line; intensity of current, 8 ampères; ultimate efficiency, 52·52 per cent.

In an experiment at the Munich Exhibition, in 1882, the generator was at Miesbach, and the electro-motor in the Exhibition palace, 35½ miles apart. The conductor was a double line of iron telegraph wire, 4½ millimetres in diameter. The machines used were two similar Gramme dynamos, series wound. The resistance of each was 470 ohms, and that of the line 950 ohms, making the total resistance of circuit, $(950+(470\times 2))=1890$ ohms.

Generator, 1611 revolutions per minute; electromotive force = 1343 volts; current intensity = ·519 ampère.

Motor, 752 revolutions per minute; counter electromotive force = 850 volts.

$$\text{Theoretical efficiency} = \frac{850}{1343} = \cdot 63.$$

The power received at Munich was ½ horse-power; and the economical efficiency was about 25 per cent.

TABLE 239.—RESULTS OF TRIALS.

	First Trial.		Second Trial.	
	Generator.	Receiver.	Generator.	Receiver.
Speed in revolutions per minute	190	248	120	277
Electromotive force (direct or inverse). Volts	5469	4242	5717	4441
Current . Ampères	7·21	7·21	7·20	7·20
Work in magnetic field . . H. P.	9·20	3·75	10·30	3·80
Electrical work in armature H. P.	53·59	41·44	55·90	43·40
Mechanical work measured in transmission dynamometer and at Prony break, H. P.	62·10	35·80	61·00	40·00

Efficiency.

	First Trial.	Second Trial.
	Per Cent.	Per Cent.
Electric	77·0	78·0
Mechanical (commercial) . .	47·7	53·4

See also *Hydraulic Transmission of Motive Power*, *post*, p. 594

HEAT.

The British unit of heat, or thermal unit, is that which can raise the temperature of one pound of water 1 degree Fahrenheit, at or near 39°·1 F., the temperature of maximum density of water.

The French thermal unit, or *calorie*, is that which can raise the temperature of one kilogramme of water, 1 degree centigrade, at or about 4° C. (=39°·1 F.).

1 calorie, or French unit of heat, is equal to 3·968 British heat-units.

1 British heat-unit is equal to ·252 calorie.

The mechanical equivalent of one British heat-unit (Joule's equivalent) is 772 foot-pounds, or 10·67 kilogrammetres.

The mechanical equivalent of one French heat-unit is 425 kilogrammetres, or 3074 foot-pounds. If calculated in terms of Joule's equivalent, the value would be 423·55 kilogrammetres, or 3063·5 foot-pounds.

1 calorie per square metre is equal to ·369 heat-unit per square foot.

1 heat-unit per square foot is equal to 2·713 calories per square metre.

1 calorie per kilogramme is equal to 1·800 heat-units per pound.

1 heat-unit per pound is equal to ·556 calorie per kilogramme.

Thermometers.

	Freezing Point.	Boiling Point.
Fahrenheit thermometer	32°	212°
Centigrade ,,	0°	100°
Réaumur ,,	0°	80°

1 degree Fahr. $= \frac{5}{9}$ Centigr. degree ; or $\frac{4}{9}$ Réaumur degree.
1 degree Centigr. $= \frac{9}{5}$ Fahr. degree ; or $\frac{4}{5}$ Réaumur degree.
1 degree Réaumur $= \frac{9}{4}$ Fahr. degree ; or $\frac{5}{4}$ Centigr. degree.

Representing the thermometric scales by their initials.

Equivalent temperature by the Centigrade scale $\text{C.} = \frac{5}{9}(\text{F.} - 32) = \frac{5}{4}\text{R.}$

do. by the Réaumur scale $\text{R.} = \frac{4}{9}(\text{F.} - 32) = \frac{4}{5}\text{C.}$

do. by the Fahrenheit scale $\text{F.} = \frac{9}{5}\text{C.} + 32 = \frac{9}{4}\text{R.} + 32.$

TABLE 240.—THERMOMETERS: FAHRENHEIT AND CENTIGRADE SCALES.

Fahr.	Centigr.	Fahr.	Centigr.	Fahr.	Centigr.	Fahr.	Centigr.
°	°	°	°	°	°	°	°
15	—9·45	69	20·56	110	43·34	151	66·11
20	—6·67	70	21·11	111	43·90	152	66·67
25	—3·90	71	21·67	112	44·45	153	67·23
30	—1·11	72	22·23	113	45·00	154	67·78
32	0·00	73	22·78	114	45·56	155	68·34
33	+0·56	74	23·34	115	46·11	156	68·90
34	1·11	75	23·90	116	46·67	157	69·45
35	1·67	76	24·45	117	47·23	158	70·00
36	2·23	77	25·00	118	47·78	159	70·56
37	2·78	78	25·56	119	48·34	160	71·11
38	3·34	79	26·12	120	48·90	161	71·67
39	3·90	80	26·67	121	49·45	162	72·23
40	4·45	81	27·23	122	50·00	163	72·78
41	5·00	82	27·78	123	50·56	164	73·34
42	5·56	83	28·34	124	51·11	165	73·90
43	6·11	84	28·89	125	51·67	166	74·45
44	6·67	85	29·45	126	52·23	167	75·00
45	7·23	86	30·00	127	52·78	168	75·56
46	7·78	87	30·55	128	53·34	169	76·11
47	8·34	88	31·11	129	53·90	170	76·67
48	8·89	89	31·67	130	54·45	171	77·23
49	9·45	90	32·22	131	55·00	172	77·78
50	10·00	91	32·78	132	55·56	173	78·34
51	10·56	92	33·33	133	56·11	174	78·90
52	11·11	93	33·89	134	56·67	175	79·45
53	11·67	94	34·45	135	57·23	176	80·00
54	12·23	95	35·00	136	57·78	177	80·56
55	12·78	96	35·56	137	58·34	178	81·11
56	13·34	97	36·11	138	58·90	179	81·67
57	13·90	98	36·67	139	59·45	180	82·23
58	14·45	99	37·23	140	60·00	181	82·78
59	15·00	100	37·78	141	60·56	182	83·34
60	15·56	101	38·34	142	61·11	183	83·90
61	16·11	102	38·90	143	61·67	184	84·45
62	16·67	103	39·45	144	62·23	185	85·00
63	17·23	104	40·00	145	62·78	186	85·56
64	17·78	105	40·56	146	63·34	187	86·11
65	18·34	106	41·11	147	63·90	188	86·67
66	18·89	107	41·67	148	64·45	189	87·23
67	19·45	108	42·23	149	65·00	190	87·78
68	20·00	109	42·78	150	65·56	191	88·34

TABLE 240.—THERMOMETERS (*continued*).

Fahr.	Centigr.	Fahr.	Centigr.	Fahr.	Centigr.	Fahr.	Centigr.
°	°	°	°	°	°	°	°
192	88·90	222	105·56	310	154·45	460	237·78
193	89·45	223	106·11	315	157·23	465	240·56
194	90·00	224	106·67	320	160·00	470	243·34
195	90·56	225	107·23	325	162·78	475	246·11
196	91·11	226	107·78	330	165·56	480	248·90
197	91·67	227	108·83	335	168·34	485	251·67
198	92·23	228	108·90	340	171·11	490	254·45
199	92·78	229	109·45	345	173·90	495	257·23
200	93·34	230	110·00	350	176·67	500	260·00
201	93·90	232	111·11	355	179·45	505	262·78
202	94·45	234	112·23	360	182·23	510	265·56
203	95·00	236	113·34	365	185·00	515	268·34
204	95·56	238	114·45	370	187·78	520	271·11
205	96·11	240	115·56	375	190·56	525	273·90
206	96·27	242	116·67	380	193·34	530	276·67
207	97·23	244	117·78	385	196·11	535	279·45
208	97·78	246	118·90	390	198·90	540	282·23
209	98·34	248	120·00	395	201·67	545	285·00
210	98·90	250	121·11	400	204·45	550	287·78
211	99·45	255	123·90	405	207·23	555	290·56
212	100·00	260	126·67	410	210·00	560	293·34
213	100·56	265	129·45	415	212·78	565	296·11
214	101·11	270	132·23	420	215·56	570	298·90
215	101·67	275	135·00	425	218·34	575	301·67
216	102·23	280	137·78	430	221·11	580	304·45
217	102·78	285	140·56	435	223·90	585	307·23
218	103·34	290	143·34	440	226·67	590	310·00
219	103·90	295	146·11	445	229·45	595	312·78
220	104·45	300	148·90	450	232·23	600	315·56
221	105·00	305	151·67	455	235·00		

TABLE 241.—THERMOMETERS: CENTIGRADE AND FAHRENHEIT SCALES.

entigr.	Fahr.	Centigr.	Fahr.	Centigr.	Fahr.	Centigr.	Fahr.
°	°	°	°	°	°	°	°
−10	14·0	3	37·4	8	46·4	13	55·4
−5	23·0	4	39·2	9	48·2	14	57·2
0	32·0	5	41·0	10	50·0	15	59·0
+1	33·8	6	42·8	11	51·8	16	60·8
2	35·6	7	44·6	12	53·6	17	62·6

TABLE 241.—THERMOMETERS (*continued*).

Centigr.	Fahr.	Centigr.	Fahr.	Centigr.	Fahr.	Centigr.	Fahr.
°	°	°	°	°	°	°	°
18	64·4	60	140·0	102	215·6	158	316·4
19	66·2	61	141·8	103	217·4	160	320·0
20	68·0	62	143·6	104	219·2	162	323·6
21	69·8	63	145·4	105	221·0	164	327·2
22	71·6	64	147·2	106	222·8	166	330·8
23	73·4	65	149·0	107	224·6	168	334·4
24	75·2	66	150·8	108	226·4	170	338·0
25	77·0	67	152·6	109	228·2	172	341·6
26	78·8	68	154·4	110	230·0	174	345·2
27	80·6	69	156·2	111	231·8	176	348·8
28	82·4	70	158·0	112	233·6	178	352·4
29	84·2	71	159·8	113	235·4	180	356·0
30	86·0	72	161·6	114	237·2	182	359·6
31	87·8	73	163·4	115	239·0	184	363·2
32	89·6	74	165·2	116	240·8	186	366·8
33	91·4	75	167·0	117	242·6	188	370·4
34	93·2	76	168·8	118	244·4	190	374·0
35	95·0	77	170·6	119	246·2	192	377·6
36	96·8	78	172·4	120	248·0	194	381·2
37	98·6	79	174·2	121	249·8	196	384·8
38	100·4	80	176·0	122	251·6	198	388·4
39	102·2	81	177·8	123	253·4	200	392·0
40	104·0	82	179·6	124	255·2	202	395·6
41	105·8	83	181·4	125	257·0	204	399·2
42	107·6	84	183·2	126	258·8	206	402·8
43	109·4	85	185·0	127	260·6	208	406·4
44	111·2	86	186·8	128	262·4	210	410·0
45	113·0	87	188·6	129	264·2	212	413·6
46	114·8	88	190·4	130	266·0	214	417·2
47	116·6	89	192·2	132	269·6	216	420·8
48	118·4	90	194·0	134	273·2	218	424·4
49	120·2	91	195·8	136	276·8	220	428·0
50	122·0	92	197·6	138	280·4	222	431·6
51	123·8	93	199·4	140	284·0	224	435·2
52	125·6	94	201·2	142	287·6	226	438·8
53	127·4	95	203·0	144	291·2	228	442·4
54	129·2	96	204·8	146	294·8	230	446·0
55	131·0	97	206·6	148	298·4	232	449·6
56	132·8	98	208·4	150	302·0	234	453·2
57	134·6	99	210·2	152	305·6	236	456·8
58	136·4	100	212·0	154	309·2	238	460·4
59	138·2	101	213·8	156	312·8	240	464·0

TABLE 241.—THERMOMETERS (*continued*).

Centigr.	Fahr.	Centigr.	Fahr.	Centigr.	Fahr.	Centigr.	Fahr.
°	°	°	°	°	°	°	°
242	467·6	262	503·6	282	539·6	302	575·6
244	471·2	264	507·2	284	543·2	304	579·2
246	474·8	266	510·8	286	546·8	306	582·8
248	478·4	268	514·4	288	550·4	308	586·4
250	482·0	270	518·0	290	554·0	310	590·0
252	485·6	272	521·6	292	557·6	312	593·6
254	489·2	274	525·2	294	561·2	314	597·2
256	492·8	276	528·8	296	564·8	316	600·8
258	496·4	278	532·4	298	568·4	318	604·4
260	500·0	280	536·0	300	572·0	320	608·0

TABLE 242.—HIGH TEMPERATURES AND CORRESPONDING LUMINOSITY. (Pouillet.)

I. TEMPERATURE OF A FIRE.

	Centigrade.	Fahrenheit.
	°	°
Nascent red	525	977
Dark red	700	1292
Nascent cherry red	800	1472
Cherry red	900	1652
Bright cherry red	1000	1832
Very deep orange	1100	2012
Bright orange	1200	2192
White	1300	2372
Dazzling white	1500	2732

II. TEMPERATURE BY FUSION OF METALS, &C.

Substance.	Temperature.	Metal.	Temperature.	Metal.	Temperature.
	Fahr. °		Fahr. °		Fahr. °
Tallow .	92	Bismuth .	518	Silver, pure	1830
Spermaceti	120	Lead . .	630	Gold coin .	2156
Wax, white	154	Zinc . .	793	Iron, cast, med.	2010
Sulphur .	239	Antimony	820	Steel . .	2550
Tin . .	455	Brass . .	1650	Wrought iron	2910

Radiation of Heat.

The heat radiated from incandescent coal or coke is expressed by the formula :—

$$R = 144\, a^{\theta}\, (a^{t} - 1) \quad . \quad . \quad . \quad . \qquad (1)$$

R = quantity of heat radiated per square foot of surface per hour, in British units.

θ = temperature of the enclosure, in Fahrenheit degrees.

t = excess temperature of surface of hot body above the temperature of the enclosure, θ, in Fahrenheit degrees.

a = constant, 1·00425.

According to the formula, the rate of radiation increases in a much more rapid ratio than the excess temperature, when the temperature of the enclosure is constant.

The heat radiated from a coal or a coke fire, is estimated to be about one-half of the whole heat generated. It increases almost as fast as the rate of combustion of the fuel per hour per square foot.

Convection of Heat, from an External Surface (Hopkins).

Surrounding Medium.		
Air . .	$C = \cdot2849t^{1\cdot233}$	(2)
Hydrogen . .	$C = \cdot9827t^{1\cdot233}$	(3)
Carbonic acid .	$C = \cdot2759t^{1\cdot233}$	(4)
Olefiant gas .	$C = \cdot3817t^{1\cdot233}$	(5)

C = quantity of heat, in English units, conveyed away from a solid body by a gas external to it, per square foot of surface per hour, under one atmosphere of pressure.

t = excess temperature of surface in Fahrenheit degrees.

TABLE 243.—COMPARATIVE CONDUCTING POWER OF SOLIDS.

Substance.	Comparative Power.	Substance.	Comparative Power.
	Gold = 1000.		Gold = 1000.
Brass . . .	749	Platinum . .	981
Copper . . .	892	Porcelain . .	12
Gold . . .	1000	Silver	973
Iron, cast . .	562	Terra Cotta .	11
„ wrought .	374	Tin	304
Lead . . .	180	Zinc	363
Marble . .	24		

TABLE 244.—COMPARATIVE ABSORBING OR RADIATING AND REFLECTING PROPERTIES OF SOLIDS.

Substance.	Absorbing or Radiating Power.	Reflecting Power
	Proportion per Cent.	Proportion per Cent.
Brass, bright polished	7	93
,, dead polished	11	89
Copper	7	93
Glass	90	10
Gold	5	95
Ice	85	15
Iron, cast, polished	25	75
,, wrought, polished	23	77
Marble	93 to 98	7 to 2
Mercury	23	77
Platinum, polished	24	76
,, sheet	17	83
Silverleaf on glass	27	73
Silver, polished	3	97
Steel, polished	17	83
Tin	15	85
Water	100	0
Writing paper	98	2
Zinc, polished	19	81

Condensation of Steam in bare Pipes exposed to Air.

Tredgold found that steam of 17½ lbs. absolute pressure per square was condensed in cast-iron pipes in a room at 60° F., at the rate of ·352 pound per square foot of exposed surface per hour; or ·0022 pound per degree of difference of temperature.

The following results were found by M. Clément. It is here assumed that the steam was of 20 lbs. absolute pressure per square inch. The pipes were exposed in a room at 77° F.

Bare Surface.	Steam Condensed per Square Foot per Hour.
Cast-iron pipe, horizontal	·328 lb.
Blackened ,, ,,	·308 ,,
Copper ,, ,,	·267 ,,
Blackened ,, ,,	·308 ,,
,, ,, upright	·359 ,,

M. Burnat found that for steam of 22 lbs. absolute pressure, vith 196°·6 F. difference of temperature, ·581 lb. was conlensed per square foot of a cast-iron pipe, nearly horizontal, per hour.

Dr. William Anderson experimented with a tubular steam-heater, of 2-inch wrought-iron tubes, in a temperature of 59° F., with steam of 51 lbs. total pressure per square inch; ·785 lb. was condensed per square foot per hour.

The foregoing results are collected in the following tablet:—

Observer.	Temperature of surrounding Air.	Difference of Temperature.	Steam consumed per Square Foot per Hour.		Heat emitted per 1° F. difference of Temperature.
			Total.	Per 1° F.	
	° Fahr.	° Fahr.	Pound.	Pound.	Units.
Clement .	77	151	·328	·00217	2·07
Tredgold. .	60	161	·352	·0022	2·10
Burnat .	36·5	196·6	·581	·0030	2·81
Anderson .	59	223	·785	·0035	3·22

From these data, the following approximate formulæ are deduced:—

Condensation of steam in cast-iron pipes, in air, per square foot of surface per hour at ordinary temperatures:—

$$s=\frac{t^2}{55000}-{\cdot}12 \quad . \quad . \quad . \quad . \quad . \quad (6)$$

Heat emitted from cast-iron pipes, in air, per square foot of surface per hour, at ordinary temperatures:—

$$h=\frac{t^2}{58}-114 \quad . \quad . \quad . \quad . \quad . \quad (7)$$

Heat emitted from cast-iron pipes, in air, per square foot of surface per degree of difference of temperature of steam and air, per hour, at ordinary temperatures.

$$h'=\frac{t}{58}-\frac{114}{t} \quad . \quad . \quad . \quad . \quad . \quad (8)$$

s=quantity of steam condensed in pounds.
h=quantity of heat emitted in units.
h'=quantity of heat emitted, per degree of difference of temperature.
t=difference of temperature, in Fahrenheit degrees.

The latent heat of steam of 22 lbs. total pressure per square inch, 950 units per pound, is employed as the heat-factor, as an average value.

The Table 245 has been calculated by means of these formulas.

TABLE 245.—STEAM CONDENSED IN BARE CAST-IRON PIPES IN AIR, AND HEAT EMITTED, AT ORDINARY TEMPERATURES.

Steam.		Difference or Excess of Temperature of Steam above 62° Fahr.	Steam Condensed per Square Foot per Hour.		Heat Emitted per Square Foot per Hour.	
Total Pressure per Square Inch.	Temperature.		Total	Per 1° F. of Difference.	Total.	Per 1° F. of Difference.
Pounds.	° Fahr.	° Fahr.	Lbs.	Pounds.	Units.	Units.
14·7	212	150	·29	·00193	276	1·84
18	222	160	·346	·00216	329	2·05
21·5	232	170	·405	·00238	384	2·26
26	242	180	·47	·00261	446	2·48
31	252	190	·54	·00284	513	2·70
36·5	262	200	·607	·00303	577	2·89
43	272	210	·682	·00325	648	3·08
51	282	220	·76	·00345	722	3·28

For the increased rate of condensation induced by a draught of air, compared with that caused in the still air of a room, a bare steam boiler, in open air, was tested. Steam of 50 lbs absolute pressure per square inch was condensed at the rate of 1·25 pounds per square foot of external surface per hour; or, for a difference of 236° of temperature, ·0053 pound per degree of difference; showing that 4·79 units of heat per degree was emitted, or a half more than from a pipe in still air.

Non-Conducting Coating for Steam Pipes.

M. Burnat's experiments were made with cast-iron steam pipes, 4·72 inches in diameter externally, ¼ inch thick, in a large unheated hall free from draughts. They were in five groups differently coated:—

1st group, coated with straw laid lengthwise, ·60 inch thick, wrapped with straw rope.

2nd group, bare.

3rd group. Each pipe laid in a pottery pipe, enclosing an air-space, coated with a mixture of loamy earth and chopped straw, covered with tresses of straw.

4th group, coated with cotton-waste, 1 inch thick, wrapped in cloth bound with cord.

5th group, coated with a plaster of clay and cow's hair, 2·36 inches thick.

The results are given in Table 246.

TABLE 246.—CONDENSATION OF STEAM IN COATED PIPES.
(Burnat.)

Absolute Pressure of Steam per Square Inch.	Temperatures.			Steam condensed per Square Foot of External Surface of Pipes per Hour.				
	Steam.	Air.	Difference.	Straw coat, 1st.	Bare, 2nd.	Pottery coat, 3rd.	Waste coat, 4th.	Plaster coat, 5th.
Lbs.	° Fahr.	° Fahr.	° Fahr.	Lb.	Lb.	Lb.	Lb.	Lb.
16·5	218·0	46·4	171·6	·139	·496	·170	·217	·254
16·5	218·0	33·8	184·2	·152	·485	·166	·205	·262
18·4	223·4	33·7	189·7	·164	·555	·186	·229	·287
18·4	223·4	27·1	196·4	·182	·571	·264	·287	·344
22·0	233·2	41·5	191·7	·246	·576	·258	·244	·320
22·0	233·2	36·5	196·7	·164	...	·158	·250	...
22·0	233·2	36·1	197·1	·162	·557	·178	·260	...
22·0	233·2	28·9	204·3	·201	·586	·264	·328	·346
25·7	241·6	43·3	198·4	·244	·645	·301	·375	·389
25·7	241·6	36·5	205·1	·274	...	·285	·369	...
29·4	249·1	43·3	205·8	·252	·721	·270	·342	·379
29·4	249·1	30·6	218·4	·225	·621	·250	·328	·336
Averages, 22·0	233·1	36·5	196·6	·200	·581	·229	·286	·324

The plaster coat, fifth group, was afterwards painted white, when an average of ·307 pound of steam was condensed per square foot per hour, against ·324 pound previously.

The bare pipe was afterwards coated with old felt, which had been treated with caoutchouc; and it condensed an average of ·313 pound of steam per square foot per hour.

The rates of condensation and of emission of heat are summarised as follows:—

TABLE 247.—SUMMARY RESULTS.

Coating of Pipe.	Steam Condensed per Square Foot per Hour.		Heat Emitted per Square Foot per Hour.	
	Total.	Per 1° F. Difference.	Total.	Per 1° F. Difference.
	Pound.	Pound.	Units.	Units.
Bare pipe	·581	·00300	552·8	2·812
Straw	·200	·00102	190·3	0·968
Pottery pipes with air-space . .	·229	·00115	224·8	1·108
Cotton waste . . .	·286	·00146	272·1	1·384
Felt	·313	·00159	297·8	1·515
Plaster	·324	·00165	308·3	1·568
The same, painted white . . .	·307	·00156	292·1	1·486

Cooling of Water in Pipes exposed to Air.

Mr. Wm. Anderson experimented with 2-inch wrought-iron pipes, $\frac{3}{16}$ inch thick, galvanised, and 4-inch cast-iron pipes, $\frac{7}{16}$ inch thick, through which hot water was passed. Results are given in Table 248. The ultimate results harmonise with those for the use of steam in pipes.

TABLE 248.—COOLING OF WATER IN PIPES EXPOSED TO AIR.

	Two-Inch Wrought-iron Pipes.				Four-Inch Cast-iron Pipes.			
Number of experiment . .	1	2	3	4	1	2	3	4
Temperature of the atmosphere Fahr.	53°	53°	52°·5	52°	60°	60°	60°	59°
Average difference of temperatures of the water and the air . Fahr.	103°·7	49°·4	25°·4	14°·3	62°·3	45°·8	33°·9	27°·3
Total heat emitted per square foot per hour. Units	233·7	104·4	46·45	19·7	99·5	69·9	49·5	38·2
Heat emitted per 1° F. difference of temperature Units.	2·25	2·11	1·83	1·39	1·59	1·53	1·46	1·40

Tredgold experimented with small vessels of different materials, in which water was cooled from a temperature of 180° to one of 159°, in a room at 58°. The heat emitted per square foot per hour per degree of mean difference of temperature was as follows:—

Tin-plate	1·37 units.
Sheet-iron	2·24 „
Glass	2·18 „

Also, in a 2½ inch cast-iron pipe, ¼ inch thick, water was cooled from 152° to 140° F., in a room at 67°. The heat emitted per square foot per hour per degree of difference of temperature was as follows:—

Ordinary rusty surface . .	1·823 units.
Black, varnished	1·900 „
White (two coats of lead paint).	1·778 „

Transmission of Heat through Metal Plates from Water to Water.

In a metal tubular refrigerator, hot wort was cooled by water at such a rate that, taking averages, 80 units of heat passed from the wort, and was absorbed by the water per square foot of cooling surface per 1° F. per difference of temperature. The water and the wort were moved in opposite directions.

M. Péclet proved experimentally that the rate of transmission of heat was directly as the difference of temperature at the two faces of metal plates.

Transmission of Heat through Metal Plates from Steam to Water.

The rate of transmission of heat from steam through a metal plate to water at the other side is practically uniform per degree of difference of temperature. The following Table gives average results of performance, from which it appears that the transmission is much more effective for evaporating than for heating water, twice as much for flat copper plate, three times as much for copper pipe, one-fourth more for cast-iron plate. Also, that pipe surface is one-fifth more effective than flat plate surface for heating, and more than twice as much for evaporation—the result of better circulation, no doubt.

TABLE 249.—HEATING AND EVAPORATING WATER BY STEAM THROUGH METALS.

Metal Surface.	Per Square Foot per 1° F. difference of Temperature.			
	Steam Condensed.		Heat Transmitted.	
	Heating.	Evaporating.	Heating.	Evaporating.
	Pounds.	Pounds.	Units.	Units.
Copper plate	·248	·483	276	534
Copper pipe	·291	1·070	312	1034
Cast-iron boiler	·077	·105	82	100

Mr. Isherwood experimented with cylindrical metal-pots, 10 inches in diameter, 21¼ inches deep; ⅛ inch, ¼ inch, and ⅜ inch thick; turned and bored. They were placed in a steam-bath of from 220° to 320° F. Water at 212° was supplied to the pots, and evaporated. The rate of evaporation per degree of difference of temperature was the same for all temperatures; and the rate was the same for the different thicknesses. The respective weights of water, and heats consumed per square foot of inside surface, per degree of difference, were as follows:—

	Water at 212°.	Heat.
Copper	·665 lb.	642·5 units.
Brass	·577 ,,	556·8 ,,
Wrought-iron	·387 ,,	373·6 ,,
Cast-iron	·327 ,,	315·7 ,,

The differences of results for the same metal evidently arise in part from the comparative activity of circulation, and in part from the condition and position of the heating surfaces.

Condensation of Steam in Pipes or Tubes by Water externally.

From the results of experiments with surface-condensers, in which the steam was passed through the tubes, it appears that 500 units of heat by condensation were transmitted per square foot of tube surface per hour per 1° F. difference of temperature. The condensers were arranged in three groups of tubes successively traversed by the condensing water. In another case, where the condenser was arranged in two groups, from 220 to 240 units were transmitted.

Mr. B. G. Nichol experimented with an ordinary surface-condenser brass tube, ¾ inch in diameter outside, No. 18 wire-gauge in thickness; encased in a 3¾ inch iron pipe. Steam of 32½ lbs. total pressure per square inch occupied the inter-space, whilst cold water at 58° F. initial temperature was run through the brass tube. Three experiments were made with the tubes in a vertical position, and three in a horizontal position.

	Vertical Position.			Horizontal Position.		
	1,	2,	3,	4,	5,	6,
Velocity of water through tube, in feet per minute,—	81,	278,	390,	78,	307,	415 feet.
Steam condensed per square foot of surface per hour, for 1° F. difference of temperature,—	·335,	·436,	·457,	·480,	·603,	·699 lb.
Heat absorbed by the water, per square foot per hour, per 1° F. difference of temperature,—	346,	449,	466,	479,	621,	696 units.

The rate of condensation was greater in the horizontal position than in the vertical position. Also, the efficiency of the condensing surface was increased by an increase of velocity of the water through the tube, nearly in the ratio of the fourth root of the velocity for vertical tubes; and nearly as the 4·5 root for horizontal tubes.

Transmission of Heat through Metal Plates or Tubes, from Air or other Dry Gas to Water.

The rate of transmission of convected heat is probably from 2 to 5 units of heat per hour per square foot of surface per 1° F. of difference of temperature.

In a locomotive fire-box, where radiant heat co-operated with convected heat, the following results have been obtained in generating steam of 80 lbs. pressure per square inch. The temperature of the fire is taken at 2000° F.

	Water Evaporated per Square Foot per Hour.	Heat Transmitted per Square Foot per Hour per 1° F. difference of Temperature.
Burning coke, 75 lbs. per square foot of grate . . .	25½ lbs.	14½ units.
Burning briquettes, 74½ lbs. per square foot of grate . . .	35 „	20 „

There are in practice little or no differences between iron, copper, and lead in evaporative activity, when the surfaces are dimmed or coated, as under ordinary conditions.

TABLE 250.—LINEAL EXPANSION OF SOLIDS AT ORDINARY TEMPERATURES (Board of Trade).

—	For 1° Fahr.	For 1° Cent.	Expansion between Freezing and Boiling Points.			
			Coefficient.	In length of Ten Feet.		Common Fraction.
	Length = 1.	Length = 1.		Foot.	Inch	
Aluminium (cast)	·00001234	·00002221	·002221	·02221	·2664	$\frac{1}{450}$
Antimony (cryst.)	·00000627	·00001129	·001129	·01129	·1336	$\frac{1}{885}$
Brass, cast	·00000957	·00001722	·001722	·01722	·2066	$\frac{1}{581}$
„ English plate	·00001052	·00001894	·001894	·01894	·2273	$\frac{1}{529}$
„ sheet	·00001040	·00001872	·001872	·01872	·2246	$\frac{1}{535}$
Brick, best stock	·00000306	·00000550	·000550	·00550	·0660	$\frac{1}{1818}$
Bronze (Baily's) Copper, 17 Tin, $2\frac{1}{2}$ Zinc, 1	·00000986	·00001774	·001774	·01774	·2129	$\frac{1}{565}$
„	·00000975	·00001755	·001755	·01755	·2106	$\frac{1}{568}$
Cement, Roman, dry	·00000797	·00001435	·001435	·01435	·1722	$\frac{1}{697}$
„ Portland (mixed), pure	·00000594	·00001070	·001070	·01070	·1284	$\frac{1}{935}$
„ „ mortar, with sand	·00000656	·00001180	·001180	·01180	·1416	$\frac{1}{847}$
Concrete: cement mortar and pebbles	·00000795	·00001430	·001430	·01430	·1716	$\frac{1}{699}$
Copper	·00000887	·00001596	·001596	·01596	·1915	$\frac{1}{625}$
Ebonite	·00004278	·00007700	·007700	·07700	·9240	$\frac{1}{130}$

TABLE 250.—LINEAL EXPANSION OF SOLIDS AT ORDINARY TEMPERATURES (*continued*).

———	For 1° Fahr.	For 1° Cent.	Expansion between Freezing and Boiling Points.			
			Coefficient.	In length of Ten Feet.		Common Fraction.
	Length = 1.	Length = 1.		Foot.	Inch.	
Glass, English flint	·00000451	·00000812	·000812	·00812	·0974	$\frac{1}{1234}$
,, French flint	·00000484	·00000872	·000892	·00892	·1070	$\frac{1}{1124}$
,, white, free from lead	·00000492	·00000886	·000886	·00886	·1063	$\frac{1}{1130}$
,, blown	·00000498	·00000896	·000896	·00896	·1075	$\frac{1}{1111}$
,, thermometer	·00000499	·00000897	·000897	·00897	·1076	$\frac{1}{1111}$
,, hard	·00000397	·00000714	·000714	·00714	·0857	$\frac{1}{1400}$
Granite, grey, dry	·00000438	·00000789	·000789	·00789	·0947	$\frac{1}{1266}$
,, red ,,	·00000498	·00000897	·000897	·00897	·1076	$\frac{1}{1111}$
Gold, pure	·00000786	·00001415	·001415	·01415	·1698	$\frac{1}{707}$
Iridium, pure	·00000356	·00000641	·000641	·00641	·0768	$\frac{1}{1562}$
Iron, wrought	·00000648	·00001166	·001166	·01166	·1399	$\frac{1}{866}$
,, Swedish	·00000636	·00001145	·001145	·01145	·1374	$\frac{1}{873}$
,, cast	·00000556	·00001001	·001001	·01001	·1201	$\frac{1}{1000}$
,, soft	·00000626	·00001126	·001126	·01126	·1351	$\frac{1}{897}$
Lead	·00001571	·00002828	·002828	·02828	·3394	$\frac{1}{353}$
Marble, moist	·00000663	·00001193	·001193	·01193	·1432	$\frac{1}{838}$
,, dry	·00000363	·00000654	·000654	·00654	·0785	$\frac{1}{1530}$
,, white Sicilian, dry	·00000786	·00001415	·001415	·01415	·1698	$\frac{1}{707}$

TABLE 250.—LINEAL EXPANSION OF SOLIDS AT ORDINARY TEMPERATURES (*continued*).

—	For 1° Fahr.	For 1° Cent.	Expansion between Freezing and Boiling Points.			
			Coefficient.	In length of Ten Feet.		Common Fraction.
	Length = 1.	Length = 1.		Foot.	Inch.	
Marble, black Galway	·00000308	·00000554	·000554	·00554	·0665	$\frac{1}{1805}$
„ Carrara	·00000471	·00000848	·000848	·00848	·1018	$\frac{1}{1179}$
Masonry, of brick in cement-mortar: headers	·00000494	·00000890	·000890	·00890	·1068	$\frac{1}{1123}$
Do. do. stretchers	·00000256	·00000460	·000460	·00460	·0552	$\frac{1}{2174}$
Mercury (cubic expansion)	·00009984	·00017971	·017971	·17971	2·1565	$\frac{1}{56}$
Nickel	·00000695	·00001251	·001251	·01251	·1501	$\frac{1}{800}$
Osmium	·00000317	·00000570	·000570	·00570	·0684	$\frac{1}{1754}$
Palladium, pure	·00000556	·00001000	·001000	·01000	·1200	$\frac{1}{1000}$
Pewter	·00001129	·00002033	·002033	·02033	·2440	$\frac{1}{494}$
Plaster, white	·00000922	·00001660	·001660	·01660	·1992	$\frac{1}{602}$
Platinum	·00000479	·00000863	·000863	·00863	·1036	$\frac{1}{1159}$
Platinum, 90 per cent. Iridium, 10 per cent. hammered and annealed	·00000476	·00000857	·000857	·00857	·1028	$\frac{1}{1167}$
Platinum, 85 per cent. Iridium, 15 per cent.	·00000453	·00000815	·000815	·00815	·0978	$\frac{1}{1227}$
Porcelain	·00000200	·00000360	·000360	·00360	·0432	$\frac{1}{2778}$

TABLE 250.—LINEAL EXPANSION OF SOLIDS AT ORDINARY TEMPERATURES (*continued*).

	For 1° Fahr.	For 1° Cent.	Expansion between Freezing and Boiling Points.			
			Coefficient.	In length of Ten Feet.		Common Fraction.
	Length=1.	Length=1.		Foot.	Inch.	
Quartz, parallel to major axis, t 0° to 40° C.	·00000434	·00000781	·000781	·00781	·0937	$\frac{1}{1280}$
,, perpendicular to major axis, t 0° to 40° C.	·00000788	·00001419	·001419	·01419	·1703	$\frac{1}{704}$
,, cubic expansion at 16° C.	·00001924	·00003463	·003463	·03463	·4155	$\frac{1}{289}$
Silver, pure	·00001079	·00001943	·001943	·01943	·2334	$\frac{1}{514}$
Slate	·00000577	·00001038	·001038	·01038	·1246	$\frac{1}{967}$
Steel, cast	·00000636	·00001144	·001144	·01144	·1373	$\frac{1}{874}$
,, tempered	·00000689	·00001240	·001240	·01240	·1488	$\frac{1}{806}$
Stone (sandstone), dry	·00000652	·00001174	·001174	·01174	·1409	$\frac{1}{852}$
,, ,, Rauville	·00000417	·00000750	·000750	·00750	·0900	$\frac{1}{1333}$
,, ,, Caen	·00000494	·00000890	·000890	·00890	·1068	$\frac{1}{1124}$
Tin	·00001163	·00002094	·002094	·02094	·2513	$\frac{1}{477}$
Wedgwood ware	·00000489	·00000881	·000881	·00881	·1057	$\frac{1}{1136}$
Wood, pine	·00000276	·00000496	·000496	·00496	·0595	$\frac{1}{2016}$
Zinc	·00001407	·00002532	·002532	·02532	·3038	$\frac{1}{395}$
Zinc, 8 Tin, 1	·00001496	·00002692	·002692	·02692	·3230	$\frac{1}{372}$

Comparative Rate of Emission of Heat from Steam Pipes in Air and in Water.

It appears that for equal total difference of temperature the rate of emission of heat from steam pipes in water amounts, in round numbers, to from 150 to 250 times the rate in air, according as the pipes are vertical or horizontal.

Comparative Rate of Emission of Heat from Water-Tubes in Air and in Water at Rest and in Motion.

It appears that the rate of emission from water-tubes in water was about twenty times the rate in air. Mr. Craddock proved it experimentally to be twenty-five times. When the water-tube was moved through the air at a speed of 59 feet per second, it was cooled in one-twelfth of the time occupied in still air. In water, moved at a speed of 3 feet per second, the water in the tube was cooled in half the time.

Expansion of Liquids.

The cubical expansion, or expansion of volume, of water, from 32° F. to 212° F. and upwards, is given in Table 252. The rate of expansion increases with the temperature. The expansion for the range of temperature from 32° to 212° is ·0466, or fully $4\frac{1}{2}$ per cent. of the volume at 32°; or an average of ·000259 per degree, or $\frac{1}{3863}$ part of the volume at 32° F.

TABLE 251.—EXPANSION OF LIQUIDS, FROM 32° TO 212° F. Volume at 32° = 1.

Liquid.	Volume at 212°.	Expansion.	Liquid.	Volume at 212°.	Expansion.
Alcohol .	1·1100	$\frac{1}{9}$	Sea water .	1·0500	$\frac{1}{20}$
Nitric acid .	1·1100	$\frac{1}{9}$	Water . .	1·0466	$\frac{1}{22}$
Olive oil .	1·0800	$\frac{1}{12}$	Mercury .	1·018	$\frac{1}{50}$
Turpentine	1·0700	$\frac{1}{14}$			

TABLE 252.—EXPANSION AND WEIGHT OF WATER AT VARIOUS TEMPERATURES.

Temperature.	Relative Volume by Expansion.	Weight of One Cubic Foot.	Weight of One Gallon.
° Fahr.		Pounds.	Pounds.
32	1·00000	62·418	10·0101
35	·99993	62·422	10·0103
39·1	·99989	62·425 maximum density	10·0112
40	·99989	62·425	10·0112
45	·99993	62·422	10·0103
46	1·00000	62·418	10·0101
50	1·00015	62·409	10·0087
52·3	1·00029	62·400 ordinary calculations.	10·0072
55	1·00038	62·394	10·0063
60	1·00074	62·372	10·0053
62 mean temperature	1·00101	62·355	10·0000
65	1·00119	62·344	9·9982
70	1·00160	62·313	9·9933
75	1·00239	62·275	9·9871
80	1·00299	62·232	9·980
85	1·00379	62·182	9·972
90	1·00459	62·133	9·964
95	1·00554	62·074	9·955
100	1·00639	62·022	9·947
105	1·00739	61·960	9·937
110	1·00889	61·868	9·922
115	1·00989	61·807	9·913
120	1·01139	61·715	9·897
125	1·01239	61·654	9·887
130	1·01390	61·563	9·873
135	1·01539	61·472	9·859
140	1·01690	61·381	9·844
145	1·01839	61·291	9·829
150	1·01989	61·201	9·815
155	1·02164	61·096	9·799
160	1·02340	60·991	9·781
165	1·02589	60·843	9·757
170	1·02690	60·783	9·748
175	1·02906	60·665	9·728
180	1·03100	60·548	9·711
185	1·03300	60·430	9·691
190	1·03500	60·314	9·672
195	1·03700	60·198	9·654
200	1·03889	60·081	9·635
205	1·0414	59·93	9·611
210	1·0434	59·82	9·594
212	1·0466	59·64	9·565
250	1·06243	58·75	9·422
300	1·09563	56·97	9·136
400	1·15056	54·25	8·700
500	1·22005	51·16	8·204

Expansion of Gases.

The volume of atmospheric air is increased in the ratio of 1 to 1·365, in rising in temperature from 32° to 212° F., under constant pressure; and when the volume is constant, the pressure is increased in the ratio of 1 to 1·3665.

The expansion under constant pressure is uniform, and is at the rate of $\frac{1}{493{\cdot}2}$ part of the volume at 32° F., for each degree of rise of temperature: say the fraction $\frac{1}{493}$. At this rate of contraction the absolute zero of the Fahrenheit scale, or point of no heat, is (493 − 32 =) − 461° F., or 461° below 0° on the scale. On the Centigrade scale, the absolute zero is —274°. The absolute temperature by the Fahrenheit scale is found by adding 461 to the temperature indicated on the thermometrical scale. For a given volume of air or other gases at a given temperature, the volume for any other temperature under a constant pressure is,—

$$V' = V\frac{t' + 461}{t + 461} \quad . \quad . \quad . \quad . \quad . \quad . \qquad (9)$$

When the initial temperature is 62° F., the formula becomes

$$V' = V\frac{t' + 461}{523} \quad . \quad . \quad . \quad . \quad . \quad . \qquad (10)$$

When the temperature is constant, the volume varies as the pressure, or

$$V' = V\frac{p}{p'} \quad . \quad . \quad . \quad . \quad . \quad . \qquad (11)$$

When the temperature and pressure change,—

$$V' = V\frac{p(t' + 461)}{p'(t + 461)} \quad . \quad . \quad . \quad . \quad . \qquad (12)$$

When the initial temperature is 62° F., and the initial pressure is 14·7 lbs. per square inch, the formula becomes

$$p' = \frac{V(t' + 461)}{35{\cdot}58\,V'} \quad . \quad . \quad . \quad . \quad . \quad . \qquad (13)$$

When in addition the volume is constant, this formula becomes

$$p' = \frac{t' + 461}{35{\cdot}58} \quad . \quad . \quad . \quad . \quad . \quad . \qquad (14)$$

The product of the volume and pressure of a constant weight of a gas varies as the absolute temperature.

$$\text{(1 pound of air) } Vp = \frac{(t + 461)}{2{\cdot}7074} \quad . \quad . \quad . \quad . \quad . \quad . \qquad (15)$$

And the volume of one pound of air at any pressure and any temperature, is

$$V = \frac{(t + 461)}{2{\cdot}7074p} \quad . \quad . \quad . \quad . \quad . \quad . \qquad (16)$$

V = initial volume of gas.
V' = final volume of gas.
t = initial temperature.
t' = final temperature.
p = initial pressure.
p' = final pressure.

Specific Heat.

The specific heat of a body is its capacity for heat relative to that of water as a standard; of which the specific heat is that required to raise the temperature of 1 pound of water at 32° F., one degree Fahrenheit: in short, the British unit of heat. The specific heat of water is not constant; but increases slightly with the temperature, in so much that the heat required to raise the temperature from 32° to 212° F., through 180 degrees, is 180·9 units; and the average specific heat is 1·005, or one-half per cent. more than that at 32° F.

The specific heat of all solids and liquids is variable, gradually augmenting with the temperature. For temperatures under 212°, they are nearly constant.

The specific heat of perfect gases is constant.

TABLE 253.—SPECIFIC HEAT OF METALS.

Antimony	·0507	Manganese	·1441
Bismuth	·0308	Mercury, solid	·0319
Brass	·0939	,, liquid	·0333
Copper	·0951	Nickel	·1086
Cymbal metal	·086	Platinum, sheet	·0324
Gold	·0324	,, spongy	·0329
Iridium	·1887	Silver	·0570
Iron, cast	·1298	Steel	·1165
,, wrought	·1138	Tin	·0569
Lead	·0314	Zinc	·0955

TABLE 254.—SPECIFIC HEAT OF OTHER MINERAL SUBSTANCES.

STONES.		CARBONACEOUS—*con.*	
Brickwork and masonry	·20	Graphite, natural	·2019
Marble	·2129	,, of blast furnaces	·497
Chalk	·2148		
Quicklime	·2169	SUNDRY.	
Magnesian limestone	·2174	Glass	·1977
		Ice	·504
CARBONACEOUS.		Phosphorus	·2503
Coal	·2411	Soda	·2311
Charcoal	·2415	Sulphate of lead	·0872
Cannel coke	·2031	,, lime	·1966
Coke of pit coal	·2008	Sulphur	·2026
Anthracite	·2017		

TABLE 255.—SPECIFIC HEAT OF LIQUIDS.

Alcohol	·6588	Turpentine	·4160
Benzine	·3932	Vinegar	·9200
Mercury	·0333	Water, at 32° F.	1·0000
Olive oil	·3096	„ 212° F.	1·0130
Sulphuric acid :—		„ 32° to 212° F.	1·0050
Density, 1·87	·3346	Wood spirit	·6009
„ 1·30	·6614		

TABLE 256.—SPECIFIC HEAT OF GASES.

For Equal Weights.	At Constant Pressure.	At Constant Volume.
Air	·2377	·1688
Carbonic acid (CO_2)	·2164	·1714
„ oxide (CO)	·2479	·1768
Hydrogen	3·4046	2·4096
Light carburetted hydrogen	·5929	·4683
Nitrogen	·2440	·1740
Oxygen	·2182	·1559
Steam, saturated	...	·3050
Steam gas	·4750	·3700
Sulphurous acid	·1553	·1246

TABLE 257.—SPECIFIC HEAT OF WATER AT VARIOUS TEMPERATURES.

Temperature.	Specific Heat.	Heat to raise 1lb. of Water from 32° F. to given Temperature.	Temperature.	Specific Heat.	Heat to raise 1lb. of Water from 32° F. to given Temperature.
° Fahr.		Units.	° Fahr.		Units.
32	1·0000	0·000	248	1·0177	217·449
50	1·0005	18·004	266	1·0204	235·791
68	1·0012	36·018	284	1·0232	254·187
86	1·0020	54·047	302	1·0262	272·628
104	1·0030	72·090	320	1·0294	291·132
122	1·0042	90·157	338	1·0328	309·690
140	1·0056	108·247	356	1·0364	328·320
158	1·0072	126·378	374	1·0401	347·004
176	1·0089	144·508	392	1·0440	365·760
194	1·0109	162·686	410	1·0481	384·588
212	1·0130	180·900	428	1·0524	403·488
230	1·0153	199·152	446	1·0568	422·478

TABLE 258.—SPECIFIC HEAT OF WOODS.

Turpentine	·467	Oak	·570
Pear tree	·500	Fir	·650

TABLE 259.—VOLUME OF 1 POUND OF AIR AT ATMOSPHERIC PRESSURE, 14·7 LBS. PER SQUARE INCH.

Temperature.	Volume of One Pound.	Temperature.	Volume of One Pound.	Temperature.	Volume of One Pound.
° Fahr.	Cubic Feet.	° Fahr.	Cubic Feet.	° Fahr.	Cubic Feet.
0	11·583	230	17·362	525	24·775
32	12·387	240	17·612	550	25·403
40	12·586	250	17·865	575	26·031
50	12·840	260	18·116	600	26·659
62	13·141	270	18·367	650	27·915
70	13·342	280	18·621	700	29·172
80	13·593	290	18·870	750	30·428
90	13·845	300	19·121	800	31·685
100	14·096	320	19·624	850	32·941
120	14·592	340	20·126	900	34·197
140	15·100	360	20·630	950	35·453
160	15·603	380	21·131	1000	36·710
180	16·106	400	21·634	1250	42·990
200	16·606	425	22·262	1500	49·274
210	16·860	450	22·890	2000	61·836
212	16·910	475	23·518	2500	74·400
220	17·111	500	24·146	3000	86·962

TABLE 260.—MELTING POINTS OF ALLOYS OF LEAD, TIN, AND BISMUTH.

	° Fahr.		° Fahr.
1 tin, 5 lead	511	6 tin, 1 lead	381
1 ,, 3 ,,	482	4 ,, 4 ,, 1 bismuth	320
1 ,, 2 ,,	441	2 ,, 2 ,, 1 ,,	292
1 ,, 1 ,,	370	1 ,, 1 ,, 1 ,,	254
2 ,, 1 ,,	340	5 ,, 3 ,, 8 ,,	202
4 ,, 1 ,,	365		

Fusible Plugs.	Soften at	Melt at
	° Fahr.	° Fahr.
2 tin, 2 lead	365	372
2 ,, 6 ,,	372	383
2 ,, 7 ,,	377½	388
2 ,, 8 ,,	395½	408

TABLE 261.—MELTING POINTS OF METALS.

	° Fahr.		° Fahr.
Aluminium	Full red heat	Iron, cast, white	1922 to 2012
Antimony	1150	„ wrought	2912
Bismuth	507	Lead	617
Bronze	1690	Mercury	—39
Copper	1996	Silver	1873
Gold, standard	2156	Steel	2372 to 2552
„ pure	2282	Tin	442
Iron, cast, gray	2012	Zinc	773

TABLE 262.—MELTING POINTS OF SUNDRY SOLIDS.

	° Fahr.		° Fahr.
Carbonic acid	—108	Spermaceti	120
Ice	32	Sulphur	239
Nitro-glycerine	45	Tallow	92
Phosphorus	112	Turpentine	14
Stearine	109 to 120	Wax, rough	142
		„ bleached	154

TABLE 263.—BOILING POINTS OF LIQUIDS, AND HEAT OF EVAPORATION.

Liquid.	Boiling Point.	Latent Heat of Evaporation of One Pound.	Total Heat from 32° F. of One Pound.
	° Fahr.	Units.	Units.
Alcohol	173	374	461·7
Ammonia	140	...	...
Benzine	176	...	...
Linseed oil	597	...	...
Mercury	648	...	...
Sulphuric ether	100	175	210·4
Turpentine	315	124	256·6
Water	212	965·2	1146·1
„ sea	213·2	...	...
„ saturated brine	226	...	...
Wood spirit	150	475	545·9

TABLE 264.—HEAT CONDUCTING POWER OF METALS. SILVER = 1000.

(F. Crace-Calvert & R. Johnson.)

METALS.	Relative Conducting Power. Silver = 1000.
Silver	1000
Gold	981
Gold, with 1 per cent. of silver	840
Copper, rolled	845
Copper, cast	811
Mercury	677
Mercury, with 1·25 per cent. of tin	412
Aluminium	665
Zinc, rolled	641
Zinc, cast vertically	628
Zinc, cast horizontally	608
Cadmium	577
Wrought iron	436
Tin	422
Steel	397
Platinum	380
Sodium	365
Cast iron	359
Lead	287
Antimony, cast horizontally	215
Antimony, cast vertically	192
Bismuth	61
Influence of a non-metallic substance in combination on the conducting power of a metal.	
Influence of carbon on iron :—	
Wrought iron	436
Steel	397
Cast iron	359
Influence of arsenic on copper :—	
Cast copper	811
Copper with 1 per cent. of arsenic	570
,, ·5 ,, ,,	669
,, ·25 ,, ,,	771

TABLE 265.—FRIGORIFIC MIXTURES.

(Selection.)

Mixture.		Fall of Temperature.	Degrees of Cold Produced.
		Fahr.	Fahr.
Nitrate of ammonia	1	From + 50° to + 4°	46°
Water	1		
Phosphate of soda	9	From + 50° to — 21°	71°
Nitrate of ammonia	6		
Dilute nitric acid	4		
Muriate of soda (common salt)	1	From any temperature to — 5°	...
Snow, or pounded ice	2		
Muriate of soda	5	From any temperature to — 25°	...
Nitrate of ammonia	5		
Snow, or pounded ice	12		
Dilute sulphuric acid	2	From + 32° to — 23°	55°
Snow	3		
Potash	4	From + 32° to — 51°	83°
Snow	3		
Muriate of lime		From + 20° to — 48°	68°
Snow			

Conduction of Heat by Metals, Alloys, and Amalgams.

Messrs. F. Crace-Calvert and R. Johnson investigated the conducting powers of metals, alloys, and amalgams. Of the solid metals square bars 1 centimetre square (·39 inch), and 6 centimetres long (2·36 inches), were employed. Mercury and sodium were deposited in a box of the given dimensions to hold them. The metals and alloys were of pure metals, excepting platinum, aluminium, iron, and sodium, which were only commercially pure. Tables 264 and 266 give the results of the trials. The alloys of tin and lead, and tin and zinc, there is reason to believe, are only mixtures. The alloys of copper and tin appear to be definite chemical compounds, the observed conducting powers being widely different from the powers calculated from those of the elements. In one instance, an alloy of 68 per cent. of copper and 32 per cent. of tin has less than one-fourth of the calculated power. The low conducting powers of the commercial alloys, No. 7, are due to impurities.

Mercury, when so situated that circulation is prevented, is he worst heat-conducting metal known. The conducting power of silver, the best conductor, being 1000, that of mercury is only 54 when the column is vertical, and the source of heat is applied at the upper part of the column. When the column is horizontal, the power is 679. Water, like mercury, presents a complete barrier to conduction of heat applied at the upper end of a vertical column.

TABLE 266.—HEAT-CONDUCTING POWER OF ALLOYS AND AMALGAMS : SILVER = 1000.

(F. Crace-Calvert & R. Johnson.)

I. Alloys by which Heat is Conducted in the Ratio of the Calculated Mean Conducting Power of the Metals composing them.

ALLOY.	Proportions per Cent., by Weight.	Actual Relative Conducting Power. Silver = 1000.	Calculated Conducting Power.
1. *Tin and Lead.*			
Pb Sn^5 . .	T 73·97 L 26·03	385	386
Pb Sn	T 36·22 L 63·78	230	236
Sn Pb^5 . .	T 10·20 L 89·80	299	301
2. *Tin and Zinc.*			
Zn^5 Sn	Z 73·43 T 26·57	541	572
Zn Sn . .	Z 35·61 T 64·39	501	495
Zn Sn^5	Z 9·95 T 90·05	456	442
II. Alloys containing an Excess of the Worse-Conducting Metal.			
3. *Lead and Antimony.*			
Pb Sb . .	L 61·61 A 38·39	190	251
Pb Sb^5	L 24·30 A 75·70	179	215

TABLE 266.—HEAT-CONDUCTING POWER OF ALLOYS (*cont.*).

ALLOY.	Proportions per Cent., by Weight.	Actual Relative Conducting Power. Silver=1000.	Calculated Conducting Power.
4. *Antimony and Bismuth.*			
Sb Bi . . .	A 37·74 B 62·26	62	110
Sb Bi^5	A 10·82 B 89·18	48	75
5. *Copper and Tin.*			
Cu Sn . . .	C 34·98 T 65·02	415	558
Cu Sn^2 . . .	C 21·21 T 78·79	431	504
Cu Sn^3 . .	C 15·21 T 84·79	423	481
Cu Sn^4 . . .	C 11·86 T 88·14	406	468
Cu Sn^5 . .	C 9·73 T 90·27	396	459
The following have excess of copper :—			
Sn Cu^3 . . .	T 38·21 C 61·79	494	670
Sn Cu^4 . .	T 31·73 C 68·27	155	686
Sn Cu^5 . . .	T 27·10 C 72·90	207	705
6. *Zinc and Copper.*			
Cu Zn . .	C 49·32 Z 50·68	688	718
Cu Zn^2 . . .	C 32·74 Z 67·26	428	687
Cu Zn^3 . .	C 24·64 Z 75·36	531	672
Cu Zn^4 . . .	C 19·57 Z 80·43	589	663
Cu Zn^5 . .	C 16·30 Z 83·70	595	657

TABLE 266.—HEAT-CONDUCTING POWER OF ALLOYS (*cont.*)

ALLOY.	Proportions per Cent., by Weight.	Actual Relative Conducting Power. Silver=1000.	Calculated Conducting Power.
6. *Zinc and Copper* (*continued*). The following have excess of copper :—			
$Zn\,Cu^2$	Z 33·94 C 66·06	621	748
$Zn\,Cu^3$	Z 25·52 C 74·48	638	764
$Zn\,Cu^4$	Z 20·44 C 79·56	666	770
$Zn\,Cu^5$	Z 17·05 C 82·95	715	780
7. *Commercial Alloys.*			
"Yellow brass"	Copper 64·0 Zinc 56·0	558	712
"Pumps and pipes"	Copper 80 Tin 5 Zinc 7·5 Lead 7·5	426	707
"Mud plugs"	Copper 80 Tin 10 Zinc 10	394	754
"Large bearings"	Copper 84·05 Tin 12·82 Zinc 5·13	345	751
III. Amalgams (Compounds of Mercury), Solid and Semi-Solid, in which there is an Excess of the Amalgamated Metal.			
8. *Amalgams of Tin.*			
$Hg\,Sn^2$	M 45·88 T 54·12	8·65	8·11
$Hg\,Sn^3$	M 36·18 T 63·82	9·45	9·2
$Hg\,Sn^4$	M 29·84 T 70·16	9·65	9·95
$Hg\,Sn^5$	M 25·38 T 74·62	10·6	10·5

TABLE 266.—HEAT-CONDUCTING POWER OF ALLOYS (*cont.*).

ALLOY.	Proportions per Cent., by Weight.	Actual Relative Conducting Power. Silver=1000.	Calculated Conducting Power.
9. *Amalgams of Zinc.*			
Hg Zn^2	M 60·63 Z 39·37	9·7	8·97
Hg Zn^3	M 54·70 Z 45·30	10·45	10·05
Hg Zn^4	M 43·50 Z 56·50	11·00	12·08
Hg Zn^5	M 38·11 Z 61·89	13·95	13·05
10. *Amalgams of Bismuth.*			
Hg Bi^2	M 31·82 B 68·18	2·15	1·87
Hg Bi^3	M 23·86 B 76·14	2·6	1·89
Hg Bi^4	M 19·03 B 80·97	2·55	1·90
Hg Bi^5	M 15·82 B 84·18	2·35	1·91

COMBUSTION.—FUELS.

Combustion.

The volume of air consumed chemically in the combustion of fuel is expressed by the formula :—

$$A = 1{\cdot}52\ (C + 3H - {\cdot}4O) \qquad (1)$$

A = volume of air as at 62° F., and under one atmosphere of pressure, in cubic feet, per pound of fuel.
A′ = weight of air as at 62° F. per pound of fuel.
C = percentage of constituent carbon.
H = percentage of constituent hydrogen.
O = percentage of constituent oxygen.

The weight of the air thus found by volume is equal to the volume divided by 13·14. Or it is found directly by the formula :—

$$A' = \cdot 116\,(C + 3H - \cdot 4O)\,. \qquad (2)$$

In these formulas the heat evolved by the combustion of the sulphur constituent is not noticed, as it is trifling in proportion.

The volume of the volatile or gaseous products of the complete combustion of one pound of a fuel, as at 62° F., at atmospheric pressure, is, by formula,—

$$V = 1\cdot 52C + 5\cdot 52H \qquad (3)$$

The weight of the gaseous products is, by formula,—

$$w = \cdot 126C + \cdot 358H \qquad (4)$$

V = volume of gaseous products, in cubic feet.
w = weight of gaseous products, in pounds.
C = percentage of constituent carbon.
H = percentage of constituent hydrogen.

The volume at any other temperature is found by the formula for expansion of volume of gases, p. 474.

The proportion of free or unconsumed air usually present in the gaseous products is determined by multiplying the percentage of oxygen, found by analysis, by 4·35. The product is the percentage of free air in parts of the whole mixture.

The heat generated by combustion is as follows :—

Carbon	14,500	heat-units per pound.
Hydrogen	62,000	„
Sulphur	4,000	„

The heating power of fuels containing carbon and hydrogen is approximately expressed by the formula :

$$h = 145\,(C + 4\cdot 28H) \qquad (5)$$

in which h is the total heat of combustion.

The evaporative efficiency for one pound of fuel is

$$e = \cdot 15\,(C + 4\cdot 28H)\,. \qquad (6)$$

$$\text{or, } e = \frac{h}{966} \qquad (7)$$

e = weight of water evaporable from and at 212°, in pounds, per pound of fuel.

The maximum temperature of combustion of carbon is about 5000° F. ; and that of hydrogen is about 5800° F.

Fuels.

Coal consists mainly of carbon, which varies from 50 per cent. to 80 per cent., by weight, of the fuel. Lignite or brown coal contains from 56 to 76 per cent. of carbon. The average composition of British coal is, say, 80 per cent. of carbon, 5 per cent. of hydrogen, 1¼ per cent. of sulphur, 1⅓ per cent. of nitrogen, 8 per cent. of oxygen, and 4 per cent. of ash. The fixed carbon or coke averages 61 per cent. The average specific gravity is 1·279 ; average weight of a solid cubic foot, 80 pounds ; and of a cubic foot heaped, 50 pounds ; average bulk of one ton heaped, 44½ cubic feet ; equivalent evaporative efficiency, 15·40 pounds of water per pound of coal, from and at 212° F.

Bituminous coals hold from 6 per cent. to 10 per cent. of water hygroscopically ; Welsh coals from ⅝ per cent. to 2¾ per cent.

Coke contains from 85 to 97½ per cent. of carbon ; from ¾ to 2 per cent. of sulphur, and from 1½ to 14½ per cent. of ash. The average composition may be taken as 93½ per cent. of carbon, 1¼ per cent. of sulphur ; 5½ per cent. of ash. It weighs from 40lbs. to 50lbs per cubic foot solid, and about 30lbs. broken and heaped. The volume of 1 ton heaped is from 70 to 80 cubic feet ; average, 75 cubic feet. Coke is capable of absorbing from 15 to 20 per cent. of moisture. There is ordinarily from 5 per cent. to 10 per cent. of hygrometric moisture in coke.

Lignite or *brown coal* consists chiefly of carbon, oxygen, and nitrogen ; averaging in perfect lignite, 69 per cent. of carbon, 5 per cent. of hydrogen, 20 per cent. of oxygen and nitrogen, and 6 per cent. of ash. The weight is about 80 pounds per cubic foot. Imperfect lignite weighs about 72 pounds per cubic foot.

Asphalte consists, in round numbers, of 79 per cent. of carbon, 9 per cent. of hydrogen, 9 per cent. of oxygen and nitrogen, and 3 per cent. of ash. It weighs about 66 pounds per cubic foot.

Woods of various kinds are approximately the same in composition, averaging, when perfectly dry, 50 per cent. of carbon, 6 per cent. of hydrogen, 41 per cent. of oxygen, 1 per cent. of nitrogen, and 2 per cent. of ash. Green wood when cut down contains moisture to the extent of 45 per cent. of its weight. Wood kept in a dry place holds from 15 per cent. to 20 per cent. of water. In a closely packed pile of wood, consisting of uncloven stems, the interstitial space is about 30 per cent. of the gross bulk. A cord of pine-wood, in the United States of America, is 4 feet by 4 feet by 8 feet, and has a volume of

128 cubic feet. Its weight averages 2,700 pounds, or 21 pounds per cubic foot. A "corde" of wood, in France, has a volume of 4 cubic feet metres or 141 cubic feet. Ordinarily dry wood, in France, averages 20 pounds weight per cubic foot heaped, or 114 cubic feet per ton heaped.

Wood charcoal, as manufactured in the forests, consists of 79 per cent. of carbon, 2 per cent. of free hydrogen, 11 per cent. of hydrogen, oxygen, and nitrogen, and 8 per cent. of ash :—average composition. The yield of charcoal varies from 17 to 21 per cent. in weight of the wood, which is a mixture of oak, beech, poplar, willow, and elm. The weight of charcoal as manufactured, heaped, is 14 pounds per cubic foot; in small pieces, heaped, 25 pounds per cubic foot. The bulk of 1 ton heaped is 160 cubic feet and 88·5 cubic feet respectively. Charcoal holds generally 10 or 12 per cent. of moisture.

Peat, cut and dried, has a specific gravity varying from ·22 to 1·06. Ordinary air-dried peat holds from 20 per cent. to 30 per cent. of its gross weight of moisture. Perfectly dry peat contains, on an average, 59 per cent. of carbon, 6 per cent. of hydrogen, 30 per cent. of oxygen, 1¼ per cent. of nitrogen, and 4 per cent. of ash. The weight of one cubic foot, heaped or stalked, is from 6 pounds to 22½ pounds per cubic foot; or, the volume of one ton is from 370 cubic feet to 100 cubic feet. Condensed peat, such as is macerated and mixed, weighs from 44 to 57 pounds per cubic foot stalked, or the volume is from 51 to 40 cubic feet per ton.

Peat charcoal is yielded at the rate of from 30 per cent. 40 per cent. by weight of good peat. It contains from 85 to 90 per cent. of carbon, and from 10 to 15 per cent. of ash.

Straw, in its ordinary state, consists of about 16 per cent. of water, 36 per cent. of carbon, 5 per cent. of hydrogen, 38 per cent. of oxygen, ½ per cent. of nitrogen, and 4½ per cent. of ash. Pressed straw weighs from 6 pounds to 8 pounds per cubic foot.

Petroleum consists of about 85 per cent. of carbon, 13 per cent. of hydrogen, and 2 per cent. of oxygen; having ·87 specific gravity, and weighing 8·70 pounds per gallon. *Petroleum oils* consist of about 73 per cent. of carbon, and 27 per cent. of hydrogen; having ·71 specific gravity, and weighing 7·10 pounds per gallon.

Coal Gas, which will be noticed in detail, consists, in round numbers, of 12 per cent. of olefiant gas, 53 per cent. of marsh gas, 14 per cent. of carbonic oxide, 8 per cent. of hydrogen, 6 per cent. of nitrogen, and a small fraction of oxygen.

For the above-named fuels, the Heat of Combustion is recorded in Table 267, with the quantity of air chemically consumed.

TABLE 267.—HEAT OF COMBUSTION OF FUELS.

Fuel.	Air Chemically Consumed per Pound of Fuel.		Total Heat of Combustion of One Pound of Fuel.	Equivalent Evaporative Power, from and at 212° F., Water per Pound of Fuel.
	Pounds.	Cub. Ft. at 62° F.	Units.	Pounds.
Coal of average composition	10·7	140	14,700	15·22
Coke	10·81	142	13,548	14·02
Lignite	8·85	116	13,108	13·57
Asphalte	11·85	156	17,040	17·64
Wood, desiccated	6·09	80	10,974	11·36
Wood, 25 per cent. moisture	4·57	60	7,951	8·20
Wood charcoal, desiccated	9·51	125	13,006	13·46
Peat, desiccated	7·52	99	12,279	12·71
Peat, 30 per cent. moisture	5·24	69	8,260	9·53
Peat charcoal, desiccated	9·9	130	12,325	12·76
Straw	4·26	56	8,144	8·43
Petroleum	14·33	188	20,411	21·13
Petroleum oils	17·93	235	27,531	28·50
Coal gas, per cubic foot at 62° F.	...	...	630	·70

WARMING AND VENTILATION.—COOKING-STOVES.

Warming and Ventilation.

The quantity of air required for ventilation of buildings is variously estimated at from 3½ cubic feet to 20 cubic feet per minute, or from 210 to 1,200 cubic feet per hour per head of inmates in ordinary good health. In public schools, 1,800 cubic feet per hour per head is recommended; for theatres and concert-halls, from 1,500 to 3,000 cubic feet; for hospitals, from 4,000 to 6,000 cubic feet. For each lamp or gas-burner employed, from 30 to 60 cubic feet per hour should be provided.

In warming dwelling-rooms by open coal fires and by close stoves, the results of the tests made by Mr. D. K. Clark for the Smoke Abatement Committee, showed that the heat of combustion was distributed as follows:—

	Open Grates.	Close Stoves.
Heat carried up the chimney .	43	24
Radiated and conducted heat absorbed by the walls . .	42	54
Heat lost by radiation and conduction externally, and heat lost by imperfection of combustion	15	22
	100	100

The grates and stoves were tested in rooms 15 feet square, 17 feet total height; having 3,600 cubic feet of capacity.

	Open Grates.	Close Stoves.
Average weight of Wallsend coal consumed per hour	3·65 lbs.	3·87 lbs.
Average rise of temperature maintained in the room . . .	10·83° F.	17·74° F.
Average rise of temperature maintained per lb. of coal consumed per hour	3·22° F.	4·48° F.

It was shown that, of the open grates, those constructed on the principle of drawing the combustible gases through the incandescent fuel, were the most efficient; and that, of these, the best were those in which the fresh fuel was supplied below the fire, the combustible gases rising upwards through it. Ordinary open fires, having either bottom grids or solid floors, were the least effective for warming relatively to the quantity of coal consumed per hour.

The efficiency generally varied inversely as the depth of the smoke-shade at the top of the chimney.

The velocity and temperature of draught in the chimney, which was 8¾ inches in diameter, were as follows:—

	Open Grates.	Close Stoves.
Velocity of draught in feet per minute	376 ft.	275 ft.

	Open Grates.	Close Stoves.
Temperature in chimney . .	197° F.	200° F.
Actual volume of gases passed up the chimney in cubic feet per hour	9,400 ft.	6,880 ft.
Equivalent volume, as for 62° F. in cubic feet	7,471 „	5,443 „
Equivalent volume, per lb. of coal, in cubic feet	2,099 „	1,158 „
Percentage volume of burnt gases in chimney	7 per cent.	12½ per cent.
Percentage volume of atmospheric air in chimney	93 „	87½ „

Heating by Steam ("Steam").

In heating buildings by steam, the boiler power and pipe surface depend much upon the kind of building and the situation. If heating be done by indirect radiation, from 50 to 100 per cent. more heat is required than for direct radiation.

RULE.—*For direct radiating surface.* Add together the area of glass in the windows in square feet, the volume of air in cubic feet required to be changed per minute, and one-twentieth of the surface of external wall and roof. Multiply the sum by the difference between the required temperature of the room and the minimum temperature of the external air; divide the product by the difference between the temperature of the steam in the pipes and the required temperature of the room. The quotient is the required radiating surface in square feet.

Each square foot of radiating surface gives off, in average practice, three heat-units per hour for each degree of difference of temperature between the steam inside and the air outside; varying 50 per cent. more or less.

In *indirect heating*, the efficiency of the radiating surface increases, and the temperature of the air diminishes, when the quantity of air passed through the coil increases. Thus, one square foot of radiating surface, with steam at 212° F., will heat 100 cubic feet of air per hour from 32° to 150°; or 300 cubic feet from 32° to 100°, in the same time. Small pipes are more effective than large pipes. When the diameter is doubled, 20 per cent. additional surface should be allowed; for three times the diameter, 30 per cent.

One square foot of boiler surface can supply to from 7 to 10 square feet of radiating surface. Each horse-power of boiler,

—measured by the evaporation of 30 pounds of water under 75 lbs. pressure, per hour—will supply to from 240 to 360 feet of 1-inch steam pipe, or from 80 to 120 square feet of radiating surface.

Under ordinary conditions, one horse-power will heat various buildings as follows :—

	Cubic feet.
Brick dwellings, in blocks, as in cities	15,000 to 20,000
„ stores	10,000 to 15,000
„ dwellings, exposed on all sides	10,000 to 15,000
„ mills, shops, factories, &c.	7,000 to 10,000
Wooden dwellings, exposed	7,000 to 10,000
Foundries and wooden shops	6,000 to 10,000
Exhibition buildings, largely of glass	4,000 to 15,000

Heating Rooms by Hot Water.

Mr. Hood allows one square foot of direct heating surface of boilers, or three square feet of flue-surface for every 40 feet of 4-inch pipe containing hot water for heating buildings ; and, allowing about 10 pounds of good coal consumed per hour per square foot of fire-grate, 20 square inches area of grate suffice for heating 40 feet of 4-inch pipe.

Mr. Jones makes the following allowance of fire-grate per 100 feet of 4-inch pipe, for different kinds of boiler :—

	Grate-area.
Plain saddle	50 square inches.
Cheek-end saddle	45 „ „
Chambered saddle	40 „ „
Double-chambered saddle	35 „ „
Trentham vertical cylindrical	35 „ „

Mr. Hood gives the following rule for the length of 4-inch pipe required to heat 1,000 cubic feet of air per minute :—

Multiply the volume of air in cubic feet to be warmed per minute, by the difference of the temperature in the room and the external temperature, and by 0·56, and divide the product by the difference of the internal temperature and that of the pipes. The quotient is the length of 4-inch pipe in feet.

The following, in Table 268, are a selection of values calculated by this rule :—

TABLE 268.—LENGTH OF 4-INCH PIPE TO HEAT 1,000 CUBIC FEET OF AIR PER MINUTE.

Temperature of the Pipe, 200° F.

External Temperature.	Temperature of the Room (Fahr.).						
	50°	55°	60°	65°	70°	75°	80°
° Fahr.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
10	150	174	200	229	259	292	328
16	127	151	176	204	233	265	300
20	112	135	160	187	216	247	281
24	97	120	144	170	199	229	262
32	67	89	112	137	164	193	225
40	37	58	80	104	129	157	187
44	22	42	64	87	112	139	168
50	...	19	40	62	86	112	140
52	...	11	32	54	77	103	131

Mr. Jones gives the following Table 269, for appproximate lengths of 4-inch pipe required for every 1,000 cubic feet. The required lengths may be varied to suit special conditions.

TABLE 269.—LENGTH OF 4-INCH PIPE REQUIRED FOR EVERY 1,000 CUBIC FEET.

Building.	Temperature Required.	Length of Pipe.
	° Fahr.	Feet.
Public buildings	55	6 to 7
Workshops, warehouses, &c. . .	55	6 to 7
Schools, churches, offices, bed-rooms, &c.	60	7 to 8
Shops, waiting rooms, &c. . . .	60	10 to 11
Living rooms	65	10 to 11
Drying stoves (closed rooms) . .	100	100
,, ,, . .	110	120
,, ,, . .	120	170
,, ,, . .	130	240
Conservatories, greenhouses, &c. .	45 to 50	35
Ferneries, &c.	50 to 55	40
Vineries, stoves	55 to 60	45
,, ,, ...	60 to 65	50
Orchids, stoves	65 to 70	55
,, ,, ...	70 to 75	60
Pineries, forcing houses . . .	75 to 80	70

Distribution of Heat in Furnaces.

In melting pig-iron in an ordinary cupola by the combustion 30 per cent. of its weight of coke, Peclet estimated that 4 per cent. only of the heat of combustion was actually tilised.

In an ordinary metallurgical re-heating furnace, one ton of oal is consumed in heating 1⅗ tons of wrought-iron to the elding point, 2,700° F.; showing that only 4¼ per cent. of he whole heat generated is appropriated by the metal.

Barely 1½ per cent. of the whole heat generated is absorbed n melting pot steel in ordinary furnaces. In the Siemens egenerative furnace, a ton of steel is melted for the combusion of 12 cwts. of small coal, showing that 6 per cent. of the eat produced is utilised.

Sir I. Lowthian Bell's estimate of the distribution of heat in a blast furnace from Durham coke, which contains 92·5 per cent. of carbon, for the production of 1 ton of pig-iron is as follows :—He assumes that 30·4 per cent. of the carbon of the fuel—Durham coke—which escapes in a gaseous form, is carbonic acid; and that, therefore, only 51·27 per cent. of the heating power of the fuel is developed, and the remaining 48·73 per cent. leaves the tunnel head undeveloped. He adopts as a unit of heat, the heat required to raise the temperature of 112 pounds of water 1° centigrade. To produce 1 ton of pig-iron there are required 11 cwts. of limestone and 49 cwts. of calcined ironstone. The ironstone consists of 18·6 cwts. of iron, 9 cwts. of oxygen, and 21·4 cwts. of earths.

For 1 ton of Pig-Iron.

		Units.	Per cent.
Evaporation of water in coke and chemical action in smelting		48,354	54·1
Fusion of pig-iron		6,600	7·4
Fusion of slag		15,356	17·2
Expansion of blast		3,700	4·1
For direct work of furnace		74,010	82·8
Loss by radiation through the walls	3,600		
Carried away by tuyere water	1,800		
Sensible heat of gaseous products	10,000		
Waste		15,400	17·2
Total heat generated in the furnace		89,410	100·0

Gas-Heating Stoves and Fires.

The results of Mr. D. K. Clark's test-trials of Gas-Heating Stoves and Fires of various classes, are summarised in Table 270.

TABLE 270.—AVERAGE RESULTS OF TEST-TRIALS OF GAS-HEATING STOVES AND FIRES.

Classes of Stoves.	External Temperature.	Temperature in the Testing Room.	Difference, or Elevation of Temperature.	Gas Consumed per Hour.	Gas per Hour per Degree of Elevation of Temperature.	Room Space per Cubic Foot of Gas per Hour per Degree of Elevation of Temperature.
	° Fahr.	° Fahr.	° Fahr.	Cub. Ft.	Cub. Ft.	Cub. Ft.
I. Close stoves . . .	57·1	64·3	7·2	10·9	1·65	218
II. Open stoves :—						
Asbestos fuel stoves .	57·4	72·1	14·7	28·7	2·05	175
Tile stoves . . .	59·7	69·2	9·5	16·9	1·84	195
III. Gas baskets or gas fires :						
Reflector stoves . .	58·7	66·5	7·8	11·1	1·55	232
Gas fires . . .	55·8	63·7	7·9	12·2	1·57	229

The volume of the testing-room was about 3,600 cubic feet. The consumption of gas per hour per degree of elevation of temperature is the measure of relative effectiveness : showing that the reflector stoves were the most effective, consuming about 1½ cubic feet of gas per hour per degree. Gas baskets, or gas fires, were practically of equal efficiency with the reflector stoves. Next in order, are close stoves, then tile stoves ; and, lastly, asbestos fuel stoves, consuming 2 cubic feet of gas per hour per degree.

The ventilation of the room, as dependent on draught in the chimney, averaged from 6,000 to 10,000 cubic feet of air, as at 62° F., per hour : showing that a volume of air of from twice to thrice the capacity of the room, was passed up the chimney per hour. By the natural draught in the chimney independent of the augmentation of draught by the stove heat, 2,400 cubic feet of air passed up the chimney per hour.

The average efficiency of the stoves was upwards of 90 per cent. ; or, less than 10 per cent. of the heat generated was wasted up the chimney.

Cooking Ranges.

From the average results of tests of Cooking Ranges at the Smoke Abatement Exhibition, it appears that a joint from the loin weighing 12½ lbs., and a sample of puff pastry following the joint, were roasted and baked in two hours, with a consumption of 17 pounds of hard steam coal.

Cooking with Gas.*

From the average results of numerous test-trials of gas-cooking stoves, having burners inside, in roasting legs of mutton weighing from 8 lbs. to 9 lbs. each, the loss of weight and net weight were as follows:—

Average distribution of Joints when very well done.

Joint as cooked . . .	6 lbs. 7 oz. or	77 per cent.
Dripping	1 „ 0 „ „	12 „ „
Loss by evaporation . .	0 „ 15 „ „	11 „ „
	8 lbs. 6 oz. or	100 per cent.

The bone of a leg of mutton weighed 1 pound.

The average temperature in the oven was 378° F. The average length of time roasting was 2 hours 16 minutes; or at the rate of a quarter of an hour per pound weight of the joint, with 16 minutes for the odd 6 ounces. The average quantity of gas consumed while roasting was 22·6 cubic feet of the average temperature 56° F., or at the rate of 2·70 cubic feet per pound of fresh joint, and of 10 cubic feet per hour. Adding the gas consumed in heating up the stoves, which was an average of 3·40 cubic feet, the sum is 26 cubic feet of gas; the total average consumption being at the rate of 3·1 cubic feet per pound of the fresh joint. The average capacity of the ovens was 2·54 cubic feet, represented nearly by that of Davis's No. 9 Stove, which is 22 inches high above the burners, and 14½ inches square. The flavour of the meat roasted by plain gas was decidedly better than that of the meat roasted by atmospheric gas.

Externally heated stoves consumed about one-third more gas than internally heated stoves.

The distribution of the heat of combustion of the 22 cubic feet of gas consumed in roasting the joint, averaging for 25 trials, was as follows:—

	Heat Units.		Gas.—Cubic Feet at 62° F.		Per cent.
Roasting the joint . .	2,203	or	3·54	or	16·1
Carried off in the burnt gases	585	„	0·94	„	4·3
Dispersed by external radiation and conduction	10,896	„	17·52	„	79·6
	13,684	„	22·0	„	100·0

Showing that barely one-sixth of the whole of the heat generated was utilised in roasting; that the proportion of heat carried off in the burnt gases was comparatively insignificant, and that four-fifths of the total heat was dispersed wastefully.

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* See *International Electric and Gas Exhibition*, 1882–83: *Report on the Gas Section*, by D. K. Clark.

STEAM.

The leading properties of saturated steam are stated in Table 271 (p. 498). The specific heat of saturated steam is ·305 at constant volume. That of steam gas is ·3643 at constant volume, and ·475 at constant pressure.

Steam of from 25 lbs. to 215 lbs. absolute pressure flows into the atmosphere, at a velocity averaging about 900 feet per second, as calculated for constant density,—that is to say, on the assumption that the steam does not expand in the course of the outflow. It actually expands and attains a velocity by expansion averaging 1450 feet per second.

Equivalent Weight of Steam formed from and at 212° *F.*—Let w = the weight of water evaporated per pound of a fuel, from water supplied at the temperature t, into steam of the total heat H, measured from 32° F. Let w', t', and H′, be the corresponding values for steam of any other pressure. Then the total heat expended in evaporating 1 pound of water is $H + 32 - t$, or $H' + 32 - t$; and

$$w' = w \frac{H + 32 - t}{H' + 32 - t'} \quad \ldots\ldots \quad (1)$$

Let H′ be the total heat of steam generated at 212° F., or 1146 units; and $t' = 212°$ E. By substitution and reduction,

$$w' = w \frac{H + 32 - t}{966} \quad \ldots\ldots \quad (2)$$

in which w' is the equivalent weight of water evaporated from and at 212° F.

Rule.—*To find the equivalent weight of water evaporated from and at* 212° *F., when a given weight of water is supplied at a given temperature, and evaporated under a given pressure.*—Find in Table 271, the total heat of the steam generated at the given absolute pressure; add 32 to it. and from the sum subtract the temperature of the feed-water; divide the remainder by 966, and multiply the quotient by the given weight of water. The product is the equivalent weight of water as evaporated from and at 212° F.

Moisture or Priming in Steam.

Blow a quantity of the so-called steam into a vessel holding a given weight of cold water: noting the pressure and the weight of the steam blown in, and the initial and final temperatures of the mixture. An addition is to be made to the initial weight of water, to represent the weight of water equivalent to that of the vessel containing the water, in terms of their respective specific heats. A corresponding addition is to be made for such portion of the apparatus as is immersed in the water.

Let W = weight of condensing water, plus the equivalent weight of the receiver and apparatus immersed in the water.

w = weight of nominal steam discharged into the vessel under water.

$W + w$ = gross weight of mixture of nominal steam and condensing water.

H = total heat of one pound of the steam, reckoned from the temperature of the condensing water.

Hw = total heat delivered by the gross weight of nominal steam discharged, taken as dry steam.

t = initial temperature of condensing water.

t' = final do. do. do.

s = augmentation of specific heat of water due to rise of temperature.

L = latent heat of one pound of steam of the given initial pressure.

Lw = latent heat of steam discharged into the vessel, taking it as dry steam.

P = weight of priming or moisture in percentage of the gross weight of nominal steam.

$$P = 100 \frac{Hw - [(W + w) \times (t' - t + s)]}{Lw} \quad . \quad . \quad . \quad (3)$$

RULE.—*To determine the proportion of moisture or priming in steam.*—To the rise of temperature add the augmentation of specific heat of the water. Multiply the gross weight of nominal steam and condensing water by this sum, and deduct the product from the constituent or total heat of the weight discharged into the vessel, taken as dry steam; and reckoned from the temperature of the condensing water. Multiply the remainder by 100, and divide by the latent heat of the steam taken as dry. The quotient is the proportion of water in percentage of the gross weight of nominal steam.

If there be no remainder, the steam is taken as dry. If, on the contrary, the product be greater than the constituent heat, the difference is evidence of superheated steam, the percentage quantity of which is found by multiplying it by 100, and dividing by the given constituent heat.

TABLE 271.—SATURATED STEAM.

Absolute Pressure per Square Inch. 1.	Temperatures. 2.	Total Latent Heat of Steam from Water supplied at 32° F. 6.	Water-heat of Steam (to raise Temperature of Water from 32° F.). 7.	Total Heat of One Pound of Steam from Water supplied at 32° F. 3.	Density, or Weight of One Cubic Foot of Steam. 8.	Volume of One Pound of Steam. 9.	Relative Volume, or Cubic Feet of Steam from One Cubic Foot of Water. 10.
Lbs.	° Fahr.	Units.	Units.	Units.	Lbs.	Cub. Ft.	Rel. Vol.
0·5	80·2	1058·4	47·1	1105·5	·001376	726·608	45307·5
1	102·1	1042·9	69·6	1112·5	·003027	330·360	20599·1
1·5	115·9	1033·2	83·5	1116·7	·004433	225·580	14066·1
2	126·3	1025·8	93·9	1119·7	·005811	172·080	10730·0
2·5	134·6	1019·9	102·6	1122·5	·007169	139·488	8697·8
3	141·6	1015·0	109·6	1124·6	·008511	117·500	7326·5
3·5	147·7	1010·6	115·8	1126·4	·009839	101·632	6337·3
4	153·1	1006·8	121·3	1128·1	·01116	89·632	5589·0
4·5	157·9	1003·4	126·2	1129·6	·01246	80·231	5002·6
5	162·3	1000·3	130·6	1130·9	·01370	72·991	4551·3
5·5	166·4	997·4	134·7	1132·1	·01505	66·428	4142·1
6	170·2	994·7	138·6	1133·3	·01634	61·201	3816·2
6·5	173·6	992·3	142·0	1134·3	·01762	56·761	3539·3
7	176·9	990·0	145·3	1135·3	·01889	52·936	3300·9
7·5	180·0	987·8	148·5	1136·3	·02016	49·610	3093·4
8	182·9	985·7	151·5	1137·2	·02142	46·686	2911·1
8·5	185·7	983·8	154·2	1138·0	·02268	44·097	2749·7
9	188·3	981·9	156·9	1138·8	·02394	41·777	2605·0
9·5	190·8	980·1	159·4	1139·5	·02547	39·261	2448·1
10	193·3	978·4	161·9	1140·3	·02642	37·845	2359·8
10·5	195·6	976·7	164·3	1141·0	·02767	36·145	2253·8
11	197·8	975·2	166·5	1141·7	·02890	34·599	2157·4
11·5	200·1	973·6	168·8	1142·4	·03026	33·045	2060·5
12	202·0	972·2	170·8	1143·0	·03137	31·879	1987·7
12·5	204·0	970·8	172·8	1143·6	·03260	30·678	1913·0
13	205·9	969·4	174·8	1144·2	·03382	29·573	1844·0
13·5	207·8	968·1	176·7	1144·8	·03504	28·536	1779·4
14	209·6	966·8	178·5	1145·3	·03627	27·573	1719·1
14·7	212·0	965·2	180·9	1146·1	·03797	26·360	1642·0
15	213·1	964·3	182·1	1146·4	·03870	25·843	1611·6
16	216·3	962·1	185·3	1147·4	·04112	24·320	1516·3
17	219·6	959·8	188·5	1148·3	·04253	23·513	1466·1
18	222·4	957·7	191·5	1149·2	·04594	21·766	1357·4
19	225·3	955·7	194·4	1150·1	·04834	20·687	1290·0

TABLE 271.—SATURATED STEAM (*continued*).

Absolute Pressure per Square Inch. 1.	Temperatures. 2.	Total Latent Heat of Steam from Water supplied at 32° F. 6.	Water-heat of Steam (to raise Temperature of Water from 32° F.). 7.	Total Heat of One Pound of Steam from Water supplied at 32° F. 3.	Density, or Weight of One Cubic Foot of Steam. 8.	Volume of One Pound of Steam. 9.	Relative Volume, or Cubic Feet of Steam from One Cubic Foot of Water. 10.
Lbs.	° Fahr.	Units.	Units.	Units.	Lbs.	Cub. Ft.	Rel. Vol.
20	228·0	953·8	197·1	1150·9	·05074	19·710	1229·0
21	230·6	951·9	199·8	1151·7	·05311	18·828	1174·0
22	233·1	950·2	202·3	1152·5	·05549	18·022	1123·8
23	235·5	948·5	204·7	1153·2	·05786	17·282	1077·6
24	237·8	946·9	207·0	1153·9	·06023	16·603	1035·2
25	240·1	945·3	209·3	1154·6	·06259	15·977	996·2
26	242·3	943·7	211·6	1155·3	·06495	15·401	960·2
27	244·4	942·2	213·6	1155·8	·06728	14·863	926·8
28	246·4	940·8	215·6	1156·4	·06971	14·345	894·5
29	248·4	939·4	217·7	1157·1	·07196	13·896	866·5
30	250·4	937·9	219·9	1157·8	·07430	13·459	839·2
31	252·2	936·7	221·7	1158·4	·07663	13·050	813·7
32	254·1	935·3	223·6	1158·9	·07894	12·666	789·8
33	255·9	934·0	225·5	1159·5	·08128	12·300	767·1
34	257·6	932·8	227·2	1160·0	·08358	11·964	746·0
35	259·3	931·6	228·9	1160·5	·08590	11·640	725·9
36	260·9	930·5	230·5	1161·0	·08821	11·337	706·9
37	262·6	929·3	232·2	1161·5	·09050	11·050	689·0
38	264·2	928·2	233·8	1162·0	·09282	10·773	671·7
39	265·8	927·1	235·4	1162·5	·09510	10·515	655·6
40	267·3	926·0	236·9	1162·9	·09740	10·267	640·2
41	268·7	924·9	238·5	1163·4	·09946	10·054	626·9
42	270·2	923·9	239·9	1163·8	·1020	9·806	611·4
43	271·6	922·9	241·3	1164·2	·1042	9·592	598·1
44	273·0	921·9	242·7	1164·6	·1065	9·386	585·3
45	274·4	920·9	244·2	1165·1	·1088	9·191	573·1
46	275·8	919·9	245·6	1165·5	·1111	9·003	561·4
47	277·1	919·0	246·9	1165·9	·1134	8·821	550·0
48	278·4	918·1	248·2	1166·3	·1156	8·650	539·3
49	279·7	917·2	249·5	1166·7	·1179	8·482	528·9
50	281·0	916·3	250·8	1167·1	·1202	8·322	518·9
51	282·3	915·4	252·1	1167·5	·1224	8·170	509·4
52	283·5	914·5	253·4	1167·9	·1247	8·021	500·2
53	284·7	913·6	254·7	1168·3	·1269	7·880	491·3

Table 271.—Saturated Steam (*continued*).

Absolute Pressure per Square Inch. 1.	Temperatures. 2.	Total Latent Heat of Steam from Water supplied at 32° F. 6.	Water-heat of Steam (to raise Temperature of Water from 32° F.). 7.	Total Heat of One Pound of Steam from Water supplied at 32° F. 3.	Density, or Weight of One Cubic Foot of Steam. 8.	Volume of One Pound of Steam. 9.	Relative Volume, or Cubic Feet of Steam from One Cubic Foot of Water. 10.
Lbs.	° Fahr.	Units.	Units.	Units.	Lbs.	Cub. Ft.	Rel. Vol.
54	285·9	912·8	255·8	1168·6	·1292	7·741	482·7
55	287·1	912·0	257·0	1169·0	·1314	7·610	474·5
56	288·2	911·2	258·1	1169·3	·1337	7·482	466·5
57	289·3	910·4	259·3	1169·7	·1357	7·370	459·5
58	290·4	909·6	260·4	1170·0	·1382	7·238	451·3
59	291·6	908·8	261·6	1170·4	·1404	7·123	444·2
60	292·7	908·0	262·7	1170·7	·1426	7·011	437·2
61	293·8	907·2	263·9	1171·1	·1449	6·902	430·4
62	294·8	906·4	265·0	1171·4	·1471	6·798	423·9
63	295·9	905·6	266·1	1171·7	·1493	6·696	417·5
64	296·9	904·9	267·1	1172·0	·1516	6·596	411·3
65	298·0	904·2	268·1	1172·3	·1538	6·502	405·4
66	299·0	903·5	269·1	1172·6	·1560	6·410	399·7
67	300·0	902·8	270·1	1172·9	·1583	6·318	394·0
68	300·9	902·1	271·1	1173·2	·1604	6·233	388·7
69	301·9	901·4	272·1	1173·5	·1627	6·147	383·3
70	302·9	900·8	273·0	1173·8	·1650	6·059	377·8
71	303·9	900·3	273·8	1174·1	·1671	5·984	373·1
72	304·8	899·6	274·7	1174·3	·1693	5·905	368·2
73	305·7	898·9	275·7	1174·6	·1716	5·829	363·5
74	306·6	898·2	276·7	1174·9	·1738	5·754	358·8
75	307·5	897·5	277·7	1175·2	·1760	5·683	354·4
76	308·4	896·8	278·6	1175·4	·1782	5·610	349·8
77	309·3	896·1	279·6	1175·7	·1803	5·544	345·7
78	310·2	895·5	280·5	1176·0	·1826	5·476	341·5
79	311·1	894·9	281·4	1176·3	·1848	5·411	337·4
80	312·0	894·3	282·2	1176·5	·1870	5·348	333·5
81	312·8	893·7	283·1	1176·8	·1892	5·286	329·6
82	313·6	893·1	284·0	1177·1	·1912	5·230	326·1
83	314·5	892·5	284·9	1177·4	·1936	5·167	322·2
84	315·3	892·0	285·6	1177·6	·1957	5·109	318·5
85	316·1	891·4	286·5	1177·9	·1980	5·052	315·0
86	316·9	890·8	287·3	1178·1	·2001	4·996	311·5
87	317·8	890·2	288·2	1178·4	·2023	4·942	308·2

TABLE 271.—SATURATED STEAM (*continued*).

Absolute Pressure per Square Inch. 1.	Temperatures. 2.	Total Latent Heat of Steam from Water supplied at 32° F. 6.	Water-heat of Steam (to raise Temperature of Water from 33° F.). 7.	Total Heat of One Pound of Steam from Water supplied at 32° F. 3.	Density, or Weight of One Cubic Foot of Steam. 8.	Volume of One Pound of Steam. 9.	Relative Volume, or Cubic Feet of Steam from One Cubic Foot of Water. 10.
Lbs.	° Fahr.	Units.	Units.	Units.	Lbs.	Cub. Ft.	Rel. Vol.
88	318·6	889·6	289·0	1178·6	·2046	4·889	304·8
89	319·4	889·0	289·9	1178·9	·2067	4·837	301·6
90	320·2	888·5	290·6	1179·1	·2088	4·790	298·6
91	321·0	887·9	291·4	1179·3	·2111	4·737	295·4
92	321·7	887·3	292·2	1179·5	·2133	4·688	292·3
93	322·5	886·8	293·0	1179·8	·2154	4·642	289·4
94	323·3	886·3	293·7	1180·0	·2176	4·595	286·5
95	324·1	885·8	294·5	1180·3	·2198	4·549	283·7
96	324·8	885·2	295·3	1180·5	·2220	4·505	280·9
97	325·6	884·6	296·2	1180·8	·2241	4·462	278·2
98	326·3	884·1	296·9	1181·0	·2263	4·419	275·5
99	327·1	883·6	297·6	1181·2	·2286	4·375	272·8
100	327·9	883·1	298·3	1181·4	·2307	4·335	270·3
101	328·5	882·6	299·0	1181·6	·2329	4·305	267·8
102	329·1	882·1	299·7	1181·8	·2350	4·256	265·4
103	329·9	881·6	300·4	1182·0	·2372	4·216	262·9
104	330·6	881·1	301·1	1182·2	·2393	4·178	260·5
105	331·3	880·7	301·7	1182·4	·2415	4·140	258·2
106	331·9	880·2	302·4	1182·6	·2437	4·104	255·9
107	332·6	879·7	303·1	1182·8	·2458	4·068	253·6
108	333·3	879·2	303·8	1183·0	·2480	4·033	251·4
109	334·0	878·7	304·6	1183·3	·2502	3·998	249·3
110	334·6	878·3	305·2	1183·5	·2523	3·963	247·1
111	335·3	877·8	305·9	1183·7	·2545	3·930	245·0
112	336·0	877·3	306·6	1183·9	·2566	3·897	243·0
113	336·7	876·8	307·3	1184·1	·2588	3·865	241·0
114	337·4	876·3	308·0	1184·3	·2610	3·832	238·9
115	338·0	875·9	308·6	1184·5	·2631	3·801	237·0
116	338·6	875·5	309·2	1184·7	·2653	3·770	235·0
117	339·3	875·0	309·9	1184·9	·2674	3·740	233·2
118	339·9	874·5	310·6	1185·1	·2696	3·710	231·3
119	340·5	874·1	311·2	1185·3	·2717	3·681	229·5
120	341·1	873·7	311·7	1185·4	·2738	3·652	227·7
121	341·8	873·2	312·4	1185·6	·2760	3·623	225·9

TABLE 271.—SATURATED STEAM (*continued*).

Absolute Pressure per Square Inch. 1.	Temperatures. 2.	Total Latent Heat of Steam from Water supplied at 32° F. 6.	Water-heat of Steam (to raise Temperature of Water from 32° F.). 7.	Total Heat of One Pound of Steam from Water supplied at 32° F. 3.	Density, or Weight of One Cubic Foot of Steam. 8.	Volume of One Pound of Steam. 9.	Relative Volume, or Cubic Feet of Steam from One Cubic Foot of Water. 10.
Lbs.	° Fahr.	Units.	Units.	Units.	Lbs.	Cub. Ft.	Rel. Vol.
122	342·4	872·8	313·0	1185·8	·2781	3·595	224·2
123	343·0	872·3	313·7	1186·0	·2803	3·567	222·4
124	343·6	871·9	314·3	1186·2	·2824	3·541	220·8
125	344·2	871·5	314·9	1186·4	·2846	3·514	219·1
126	344·8	871·1	315·5	1186·6	·2867	3·488	217·5
127	345·4	870·7	316·1	1186·8	·2889	3·462	215·8
128	346·0	870·2	316·7	1186·9	·2910	3·436	214·3
129	346·6	869·8	317·3	1187·1	·2931	3·411	212·7
130	347·2	869·4	317·9	1187·3	·2951	3·388	211·3
131	347·8	869·0	318·5	1187·5	·2974	3·362	209·7
132	348·3	868·6	319·0	1187·6	·2996	3·338	208·1
133	348·9	868·2	319·6	1187·8	·3017	3·315	206·7
134	349·5	867·8	320·2	1188·0	·3038	3·291	205·2
135	350·1	867·4	320·8	1188·2	·3060	3·268	203·8
136	350·6	867·0	321·3	1188·3	·3080	3·246	202·4
137	351·2	866·6	321·9	1188·5	·3102	3·224	201·0
138	351·8	866·2	322·5	1188·7	·3123	3·201	199·6
139	352·4	865·8	323·1	1188·9	·3145	3·180	198·3
140	352·9	865·4	323·6	1189·0	·3166	3·159	197·0
141	353·5	865·0	324·2	1189·2	·3187	3·138	195·6
142	354·0	864·6	324·8	1189·4	·3209	3·117	194·3
143	354·5	864·2	325·4	1189·6	·3230	3·096	193·1
144	355·0	863·9	325·8	1189·7	·3251	3·076	191·8
145	355·6	863·5	326·4	1189·9	·3272	3·056	190·6
146	356·1	863·1	326·9	1190·0	·3293	3·037	189·4
147	356·7	862·7	327·5	1190·2	·3315	3·017	188·1
148	357·2	862·3	328·0	1190·3	·3336	2·998	186·9
149	357·8	861·9	328·6	1190·5	·3357	2·979	185·7
150	358·3	861·5	329·2	1190·7	·3378	2·960	184·6
151	359·0	861·1	329·8	1190·9	·3400	2·941	183·4
152	359·5	860·7	330·3	1191·0	·3421	2·923	182·2
153	360·0	860·4	330·8	1191·2	·3442	2·905	181·2
154	360·5	860·0	331·4	1191·4	·3463	2·887	180·0
155	361·1	859·6	331·9	1191·5	·3484	2·870	179·0

TABLE 271.—SATURATED STEAM (*continued*).

Absolute Pressure per Square Inch. 1.	Temperatures. 2.	Total Latent Heat of Steam from Water supplied at 32° F. 6.	Water-heat of Steam (to raise Temperature of Water from 32° F.). 7.	Total Heat of One Pound of Steam from Water supplied at 32° F. 3.	Density, or Weight of One Cubic Foot of Steam. 8.	Volume of One Pound of Steam. 9.	Relative Volume, or Cubic Feet of Steam from One Cubic Foot of Water. 10.
Lbs.	° Fahr.	Units.	Units.	Units.	Lbs.	Cub. Ft.	Rel. Vol.
156	361·6	859·2	332·5	1191·7	·3505	2·853	177·9
157	362·1	858·9	332·9	1191·8	·3527	2·836	176·8
158	362·6	858·5	333·5	1192·0	·3548	2·818	175·7
159	363·1	858·1	334·0	1192·1	·3569	2·802	174·7
160	363·6	857·8	334·5	1192·3	·3590	2·785	173·7
165	366·0	856·2	336·7	1192·9	·3696	2·706	168·7
170	368·2	854·5	339·2	1193·7	·3801	2·631	164·1
175	370·8	852·9	341·5	1194·4	·3905	2·559	159·7
180	372·9	851·3	343·8	1195·1	·4011	2·493	155·5
185	375·3	849·6	346·2	1195·8	·4115	2·430	151·5
190	377·5	848·0	348·5	1196·5	·4220	2·370	147·8
195	379·7	846·5	350·7	1197·2	·4324	2·313	144·2
200	381·7	845·0	352·8	1197·8	·4419	2·263	141·1

STEAM ENGINES AND BOILERS.

Steam Engines.

The work of steam in the cylinder is in two parts :—the work during admission, and the work done during expansion after the steam is cut off.

The absolute work done during admission is,

$$aPl, \text{ or a } P(l'-c) \qquad (1)$$

The absolute work done during expansion to the end of the stroke, is.

$$aPl + \text{hyp. log. } R' \qquad (2)$$

Here, for purposes of calculation, the hyperbolic law of expansion is assumed ; according to which the pressure varies inversely as the volume.

The sum for these two quantities gives the total absolute work for one stroke : or, by reduction,

$$w = aP[l' \,(1 + \text{hyp. log. } R') - c] \qquad (3)$$

In this expression an absolute vacuum for the whole of the return stroke is supposed. But there is the work of back pressure of exhaust and compression to be deducted; that is:—

$$w' = a\,p'\,L. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

and the net work is $w - w'$, or

$$W = a[P\,(l'\,(1 + \text{hyp. log. } R') - c) - p'\,L]\,. \quad . \quad . \quad (5)$$

In this expression it is assumed that the whole of the steam is expanded to the end of the steam-stroke; or that there is no material loss by commencing the exhaustion of steam before the end of the stroke.

L = length of stroke, in feet.

l = period of admission, or length cut off, excluding clearance, in feet.

c = total clearance for one end of the cylinder, in parts of a foot of the stroke.

L' = length of stroke plus clearance.

l' = period of admission plus clearance.

R' = actual ratio of expansion.

a = area of piston, in square inches.

P = absolute pressure during admission, supposed uniform, in pounds per square inch of piston area.

p = average absolute positive pressure for the whole stroke, in pounds per square inch.

p' = average absolute back pressure for whole stroke, in pounds per square inch.

w = whole absolute work for one stroke, per square inch, in foot pounds.

w' = absolute work of back pressure for one stroke, per square inch in foot pounds.

W = net work for one stroke per square inch in foot pounds.

n = number of double strokes or revolutions of the engine.

The net horse-power of a double-acting steam-engine, for which the work has been calculated as above, is expressed by the following quantity:—

$$\frac{W \times n \times 2 \times a}{33000}\,; \text{ or } \frac{Wna}{16500} \quad . \quad . \quad . \quad (6)$$

To calculate the net horse-power from the ordinary indicator diagram, in which all deviations from the above ideal performance are aggregated, find the effective mean pressure $p - p'$, per square inch on the piston for the whole of the stroke, Thus:—

$$\text{I.H.P.} = \frac{(p - p') \times a \times 2L \times n}{33000}\,; \text{ or} \quad . \quad (7)$$

$$\text{I.H.P.} = \frac{(p - p')\,aLn}{16500} \quad . \quad . \quad . \quad . \quad . \quad (8)$$

In practice, the value $(p - p')$ may be taken by direct measurements of the net area of pressure circumscribed by the diagram.

TABLE 272.—WORK OF ONE POUND OF STEAM IN THE CYLINDER.

Point of Admission, or Cut-off.			Total Absolute Work done.	Steam per Total Absolute Horse-Power per Hour.	Average Total Pressure, that for 100 per cent. Admission being 1·000.	Net Capacity of Cylinder per lb. of 100 lbs. Steam (absolute pressure) admitted in one Stroke.
Per cent.		Fraction.	Ft. Lbs.	Pounds.		Cubic Feet.
90	or	$\frac{9}{10}$	63,850	31·0	·996	4·45
80	,,	$\frac{4}{5}$	70,246	28·2	·980	4·98
75	,,	$\frac{3}{4}$	73,513	26·9	·969	5·26
70			77,242	25·6	·953	5·63
66·6	,,	$\frac{2}{3}$	79,555	24·9	·942	5·87
62·5	,,	$\frac{5}{8}$	83,055	23·8	·925	6·23
60			85,125	23·3	·913	6·47
55			89,357	22·2	·888	6·98
50	,,	$\frac{1}{2}$	94,200	21·0	·860	7·61
45			98,849	20·0	·827	8·30
40	,,	$\frac{2}{5}$	104,406	19·0	·787	9·23
37·6	,,	$\frac{3}{8}$	107,050	18·5	·766	9·71
33·3	,,	$\frac{1}{3}$	112,220	17·7	·726	10·72
30	,,	$\frac{3}{10}$	116,885	16·9	·692	11·74
25	,,	$\frac{1}{4}$	124,066	16·0	·637	13·56
20	,,	$\frac{1}{5}$	132,770	14·9	·567	16·19
16·7	,,	$\frac{1}{6}$	138,130	14·34	·526	18·21
14·3	,,	$\frac{1}{7}$	142,180	13·92	·488	20·23
12·5	,,	$\frac{1}{8}$	146,325	13·53	·457	22·25
11·1	,,	$\frac{1}{9}$	148,940	13·29	·432	23·87
10·0	,,	$\frac{1}{10}$	151,370	13·08	·413	25·49
9·0	,,	$\frac{1}{11}$	152,595	12·98	·398	26·71
8·3	,,	$\frac{1}{12}$	155,200	12·75	·381	28·33
7·7	,,	$\frac{1}{13}$	156,960	12·61	·369	29·54
7·1	,,	$\frac{1}{14}$	157,975	12·53	·357	30·76
6·7	,,	$\frac{1}{15}$	158,414	12·25	·348	31·57
6·4	,,	$\frac{1}{16}$	159,433	11·83	·342	32·38

The absolute work done by one pound of steam of absolute pressure varying from 65 lbs. to 160 lbs., worked expansively, with the consumption per absolute horse-power are given approximately in the Table 272. No correction need be mad for clearance space, nor for the resistance of compression, as the period of compression can be so adjusted that the loss by resistance is compensated by the gain of exhaust steam shut into the cylinder. But, for the back pressure of exhaust, whether from the condenser or from the atmosphere, suitable allowance is to be made. The pressure during admission into the cylinder is supposed to be uniform; and the steam is supposed to be expanded to the end of the stroke.

The values in the last column.—net capacity per pound of steam of 100 lbs. absolute pressure per square inch—are to be modified for steam of other pressures in the ratio of the volume of 100 lbs. steam to that of steam of other pressures. The multipliers are here given for absolute pressures of from 65lbs. to 160lbs.:—

Pressures.	Multipliers.	Pressures.	Multipliers.	Pressures.	Multipliers.
Lbs.		Lbs.		Lbs.	
65	1·50	90	1·11	130	·781
70	1·40	95	1·05	140	·730
75	1·31	100	1·00	150	·683
80	1·24	110	·917	160	·644
85	1·17	120	·843		

The effective mean pressure in ordinary non-condensing cylinders, with ordinary slide-valve and excentric motion, or a like motion, working at average speeds, is given approximately by the equation:—

$$p = 13{\cdot}5\sqrt{a} - 28 \quad . \quad . \quad . \quad . \quad (9)$$

p = effective mean pressure, in per cent. of the maximum pressure of admission.

a = period of admission, in per cent. of the length of stroke.

For a speed of 560 feet of piston per minute, the formula is applicable without material error. For lower speeds, the values of the effective mean pressures are slightly too small; and for higher speeds slightly too great. The rule applies without material error to periods of admission of from 10 per cent. to 75 per cent., and to maximum pressures in the cylinder of from 60 lbs. to 100 lbs. or even 150 lbs. per square inch.

The Table 273 has been calculated by means of the above formula:—

TABLE 273.—EFFECTIVE MEAN PRESSURES IN NON-CONDENSING CYLINDER, FOR VARIOUS PERIODS OF ADMISSION, FROM PRACTICE.

("Railway Machinery.")

Period of Admission, in per cent. of the Stroke.	Effective Mean Pressure in per cent. of Maximum Pressure.	Period of Admission, in parts of the Stroke.	Effective Mean Pressure, in parts of Maximum Pressure.
Per Cent.	Per Cent.	Fraction.	Fraction.
10	15	1-10th	1-7th fully
12·5	20	1-8th	1-5th
15	24	...	...
17·5	28	1-6th	1-4th
20	32	1-5th	1-3rd
25	40	1-4th	1-2·5th part
30	46	...	...
35	52	1-3rd	1-2nd
40	57	...	...
45	62	...	...
50	67	1-2nd	2-3rds
55	72	...	...
60	77	...	...
65	81	2-3rds	4-5ths
70	85	...	...
75	89	3-4ths	9-10ths

When gaseous steam is expanded in the cylinder, it follows approximately the adiabatic law, the essential condition of which is that the cylinder should be non-conductive. The formula for gaseous steam is as follows :—

$$P' = P \times \left(\frac{v'}{v}\right)^{1\cdot284} \qquad (10)$$

P = absolute pressure, say in pounds per square inch, for the given volume V.

P′ = absolute pressure, in pounds per square inch, for any other volume V′.

V = initial volume, say in cubic feet.

V′ = volume by expansion, in cubic feet.

Any number of pressures with expansion may be calculated by the formula, and thus the expansion-curve may be determined; for comparison with expansive curves of ordinary practice, using saturated steam.

Valve Motions.

In slide-valves for the distribution of the steam in the cylinder—taking an ordinary valve for a three-port cylinder—the lap, or cover, is the length by which the valve when in its middle position, overlaps the steam port at each end ; the lead is the length of opening of each steam port for steam at the beginning of the stroke; and the linear advance of the valve is the sum of the lap and the lead. Inside lap is occasionally applied to slide-valves ; it is the width by which the inner edge of the valve, when the valve is in its middle position, overlaps the inner edge of the steam port. The angular advance is the angle formed by the excentric with its position at its half-stroke, when the piston is at the commencement of its stroke.

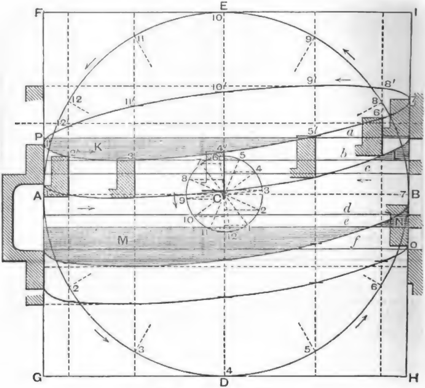

FIG. 79.—Valve-diagram.

The movements of sliding valves worked by an excentric or by an equivalent motion—as that of ordinary expansion link-motions—may be established by means of diagrams, exemplified by figure 79.

To construct this diagram, draw A B equal to the length of stroke of the piston, and bisect it at C. On C as a centre, with C A or C B as a radius, describe a circle representing the path of the crank-pin; and describe also the circle D E for that of the centre of the excentric. Through C draw the perpendicular D E, and construct a square on the large circle. Let the side H I be taken to represent the ordinary three-ported valve-face of the cylinder, and set off the ports and bars above and below the centre-line A B, and through the points draw the parallels *a*, *b*, *c*, *d*, *e*, *f*. The movement of the excentric is taken as horizontal, in the direction A B, and is directly determined by the position of the centre of the excentric; and that of the valve is for convenience taken as in the direction of D E. The middle position of the valve is represented by the dot-lines across the diagram parallel to A B; which represent its total length, and they overlie the outer edges *a* and *f* of the steam ports, by a length representing the lap. For the first position of the valve—at the beginning of the stroke—it is placed at a length equal to the linear advance, or the lap plus the lead, from its middle position, as measured on the perpendicular drawn from the corresponding first position of the excentric, No. 1. to the vertical centre-line E D. Divide both circles into 12 parts, numbered in succession from point No. 1 to point No. 12, and draw radial lines through the points of division, to represent the successive simultaneous positions of the crank and the excentric. The transverse lines drawn through the points of division on the larger circle parallel to D E, represent the corresponding positions of the piston during the inward and outward strokes; and the perpendiculars drawn to the line D E from the points of division of the smaller circle, measure the simultaneous longitudinal movements of the excentric, or the distances of the valve-edges above or below their middle positions. These are set off on the ordinates parallel to D E, and they range in elliptic curves as inscribed on the diagram, representing the whole movements of the valve for a double stroke of the piston, or one revolution of the crank.

Zeuner's valve-diagram fig. 80, affords a simple means of settling the points of the distribution of steam. Draw two lines, A B and C D, at right angles, intersecting at O; and with the radius A O, equal to half the travel of the valve, describe the circle A B, taken to represent the path of the crank-pin. Set off the diameter *a* O *a'*, at the angle *a* O C, equal to the angular advance of the excentric; and on the radii *a* O and O *a'* describe the circles *a* O and O *a'*. On the centre O, with the radius O *b*, equal to the outside lap of the valve, describe a circle cutting the circle *a* O at *b* and *c*; and from these points of intersection, draw the radii O *f* and O *g*. Draw the diameter *d* O *e* at right angles to the diameter *a* O *a'*. Taking A B for the stroke of the piston, the point *f*, is the position of the crank-pin when the valve opens for lead at

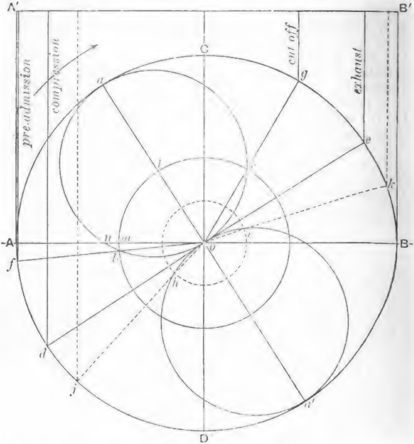

FIG. 80.—Zeuner's Valve-diagram.

A, the beginning of the stroke; *g* is the position when the steam is cut off; *e* is the position when the valve is opened for exhaust; and *d* is the position when the exhaust side of the valve is closed for compression. In this case, there is no inside lap.

For a case of inside lap on the valve, describe the circle *h i*, with a radius equal to the inside lap, cutting the circle O *a'* at *h* and *i*, and through these points draw the radii O *j*, and O *k*. The point *h*, in the outer circle, is the position of the crank-pin when the exhaust is opened, and the point *j* is the position when it is closed for compression.

Draw a parallel A′ B′ to the base-line A B, and draw ordinates to it from the several points of the distribution in the circle A B. The intersections of these ordinates with the parallel A′ B′ give the points of the distribution for the double stroke of the piston.

TABLE 274.—CORRECTIONS FOR THE POSITION OF THE PISTON, DUE TO THE OBLIQUITY OF THE CONNECTING-ROD.

Distance of Piston from Commencement of Stroke, as represented by the progress longitudinally of the Crank, in percentage of the Stroke.		Corrections for Connecting-Rods of Several Lengths related to the Length of the Crank, in percentages of the Whole Stroke.		
		Four Lengths of Crank.	Six Lengths of Crank.	Eight Lengths of Crank.
Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
0	100	0	0	0
2	98	0½	0¼	0¼
4	96	1	0½	0½
6	94	1½	1	0¾
8	92	2	1¼	1
10	90	2¼	1½	1
12	88	2¾	1¾	1½
14	86	3	2	1½
16	84	3½	2¼	1¾
18	82	3¾	2½	2
20	80	4	2¾	2
22	78	4½	3	2¼
24	76	4½	3	2¼
26	74	5	3¼	2½
28	72	5	3¼	2½
30	70	5¼	3½	2½
32	68	5½	3¾	2¾
34	66	5¾	3¾	3
36	64	6	4	3
38	62	6	4	3
40	60	6	4	3
42	58	6¼	4	3
44	56	6¼	4¼	3
46	54	6¼	4¼	3
48	52	6½	4¼	3¼
50	50	6½	4¼	3¼

The distribution is affected by the obliquity of the connecting-rod, insomuch that during the front stroke—that is the stroke made towards the crank—the piston is in advance of its normal position, as represented by the progress longitudinally of the crank-pin ; and during the back stroke, it is behind its normal position. The corrections in per cent. of the stroke are given in Table 274, for three different lengths of connecting-rod, in proportion to the length of the crank. They are additive for front strokes, and subtractive for back strokes. They have been calculated by means of the formula (11) (*Railway Machinery*).

$$x = a\,r - \sqrt{(a^2-1)r^2+b^2} \quad . \quad . \quad . \quad (11)$$

a = length of connecting-rod in parts of that of the crank.

b = distance of piston from the middle of the stroke as represented by the progress longitudinally of the crank.

r = length of crank.

x = the correction.

Rules for Valves.

1. *For the angular advance of the excentric.* Divide the linear advance by the half-travel ; the quotient is the sine of the angle of advance ; and the angle, which is acute, may be found in a table of sines.

2. *For the period of admission or point of cut-off.* Divide the lap by the half-travel of the valve ; the quotient is the sine of the angle of the excentric at the instant of cut-off ; the angle is obtuse and is found in a table of sines. From this angle subtract the angle of advance as found by Rule I. ; the difference is the angle of the crank. If this angle is obtuse, add 1 to its cosine ; if acute, subtract it from 1. The product of the sum or the difference by 50, is the percentage of admission.

3. *For the period of compression.* Subtract the cosine of the angle of advance from 1, and multiply by 50, to find the percentage of the period of compression.

These rules may be employed for link-motions ; and generally for all valve-motions based on the motion of excentrics.

By means of the first and second rules, the following table 276, has been calculated with a constant lead, $\frac{5}{16}$ inch.

When it is desired that the lap, lead, and travel of the slide-valve should bear constant ratios to each other, the following general rule is useful :—

4. Given the travel, to find the lap and lead suitable for an admission of about 75 per cent. of the stroke.

1st for lap, multiply the travel by 22, and divide by 100.

2nd for lead, multiply the travel by 7, and divide by 100.

By this rule, the Table 275, has been calculated.

TABLE 275.—LAP AND LEAD OF SLIDE-VALVES, PROPORTIONED FOR VARIOUS TRAVELS, FOR AN ADMISSION OF ABOUT 75 PER CENT. OF THE STROKE.

Travel of Valve.	Lap.	Lead.	Travel of Valve.	Lap.	Lead.
Inches.	Inches.	Inch.	Inches.	Inches.	Inch.
$1\frac{1}{2}$	·33 or $\frac{5}{16}$ $\frac{1}{64}$	·10 or $\frac{3}{32}$	$3\frac{1}{4}$	·71 or $\frac{11}{16}$ $\frac{1}{64}$	·22 or $\frac{3}{16}$ $\frac{1}{32}$
$1\frac{5}{8}$	·36 ,, $\frac{5}{16}$ $\frac{3}{64}$	·11 ,, $\frac{1}{16}$ $\frac{3}{64}$	$3\frac{1}{2}$	·77 ,, $\frac{12}{16}$ $\frac{1}{64}$	·24 ,, $\frac{3}{16}$ $\frac{3}{64}$
$1\frac{3}{4}$	·38 ,, $\frac{6}{16}$	·12 ,, $\frac{1}{8}$	$3\frac{3}{4}$	·82 ,, $\frac{13}{16}$	·26 ,, $\frac{1}{4}$
$1\frac{7}{8}$	·41 ,, $\frac{6}{16}$ $\frac{1}{32}$	·13 ,, $\frac{1}{8}$	4	·88 ,, $\frac{14}{16}$	·28 ,, $\frac{1}{4}$ $\frac{1}{32}$
2	·44 ,, $\frac{7}{16}$	·14 ,, $\frac{1}{8}$ $\frac{1}{64}$	$4\frac{1}{4}$	·93 ,, $\frac{15}{16}$	·30 ,, $\frac{1}{4}$ $\frac{3}{64}$
$2\frac{1}{8}$	·47 ,, $\frac{7}{16}$ $\frac{1}{32}$	·15 ,, $\frac{1}{8}$ $\frac{1}{32}$	$4\frac{1}{2}$	·99 ,, 1·00	·31 ,, $\frac{5}{16}$
$2\frac{1}{4}$	·50 ,, $\frac{1}{2}$	·16 ,, $\frac{1}{8}$ $\frac{1}{32}$	$4\frac{3}{4}$	1·04 ,, $1\frac{3}{64}$	·33 ,, $\frac{5}{16}$ $\frac{1}{64}$
$2\frac{3}{8}$	·52 ,, $\frac{8}{16}$ $\frac{1}{64}$	·17 ,, $\frac{1}{8}$ $\frac{3}{64}$	5	1·10 ,, $1\frac{3}{32}$	·35 ,, $\frac{5}{16}$ $\frac{1}{32}$
$2\frac{1}{2}$	·55 ,, $\frac{8}{16}$ $\frac{3}{64}$	·17 ,, $\frac{1}{8}$ $\frac{3}{64}$	$5\frac{1}{4}$	1·15 ,, $1\frac{1}{8}$ $\frac{1}{32}$	·37 ,, $\frac{3}{8}$
$2\frac{5}{8}$	·58 ,, $\frac{9}{16}$ $\frac{1}{64}$	·18 ,, $\frac{3}{16}$	$5\frac{1}{2}$	1·21 ,, $1\frac{3}{16}$ $\frac{1}{64}$	·38 ,, $\frac{3}{8}$
$2\frac{3}{4}$	·60 ,, $\frac{9}{16}$ $\frac{1}{32}$	·19 ,, $\frac{3}{16}$	$5\frac{3}{4}$	1·26 ,, $1\frac{1}{4}$	·40 ,, $\frac{3}{8}$ $\frac{1}{32}$
$2\frac{7}{8}$	·63 ,, $\frac{10}{16}$	·20 ,, $\frac{3}{16}$ $\frac{1}{64}$	6	1·32 ,, $1\frac{5}{16}$	·42 ,, $\frac{3}{8}$ $\frac{3}{64}$
3	·66 ,, $\frac{10}{16}$ $\frac{1}{32}$	·21 ,, $\frac{3}{16}$ $\frac{1}{64}$	$6\frac{3}{4}$	1·50 ,, $1\frac{1}{2}$	·47 ,, $\frac{7}{16}$ $\frac{1}{32}$

In the Table 276, following, is shown the relative distribution for a slide-valve of the proportions assumed in rule 4, above; with admissions varied from 73·5 per cent. (say 75) to 12 per cent., for the corresponding travels given in the last two columns.

TABLE 276.—DISTRIBUTION FOR VARIOUS TRAVELS OF A VALVE OF STANDARD PROPORTIONS.

Steam Cut-off.	Steam Exhausted.	Point of Compression.	Point of Admission.	Travel of the Valve. Lap 1 Inch. Lead $\frac{5}{16}$ Inch.	
Per Cent.	Per Cent.	Per Cent.	Per Cent.	Inches.	Per Cent. of Maximum Travel.
75	91	9	·62	$4\frac{1}{2}$	100
60	86	14	1·10	$3\frac{3}{4}$	83·3
50	80	20	1·90	$3\frac{3}{8}$	75
40	75	25	2·50	$3\frac{1}{32}$	67
30	68	32	4·35	$2\frac{13}{16}$	62
20	57	43	7·60	$2\frac{11}{16}$	60
12	50	50	12·25	$2\frac{5}{8}$	58·3

TABLE 277. PERIODS OF ADMISSION FOR VARYING TRAVELS AND LAPS OF THE SLIDE-VALVE.

Lead $\frac{5}{16}$ inch.

Travel.	Lap in Inches.								
	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1	$1\frac{1}{8}$	$1\frac{1}{4}$	$1\frac{3}{8}$	$1\frac{1}{2}$
	Periods of Admission in Percentages of Stroke.								
Inches.	%	%	%	%	%	%	%	%	%
$1\frac{5}{8}$	19	...	...	...	...	...	...	...	...
$1\frac{3}{4}$	39	...	...	...	...	...	...	...	...
$1\frac{7}{8}$	47	17	...	...	...	...	...	...	...
2	55	34	...	...	...	...	...	...	...
$2\frac{1}{8}$	61	42	14	...	...	...	...	...	...
$2\frac{1}{4}$	65	50	30	...	...	...	...	...	...
$2\frac{3}{8}$	68	55	38	13	...	...	...	...	...
$2\frac{1}{2}$	71	59	45	27	...	...	...	...	...
$2\frac{5}{8}$	74	63	49	36	12	...	...	...	...
$2\frac{3}{4}$	76	67	56	43	26	...	...	...	...
$2\frac{7}{8}$	78	70	59	47	32	11	...	...	...
3	80	73	62	50	38	23	...	...	...
$3\frac{1}{8}$	81	74	65	55	44	30	10	...	...
$3\frac{1}{4}$	83	76	68	59	48	34	22	...	...
$3\frac{3}{8}$	84	78	71	62	51	40	29	9	...
$3\frac{1}{2}$	85	80	73	64	53	45	34	20	...
$3\frac{5}{8}$	86	81	75	66	57	49	38	26	9
$3\frac{3}{4}$	87	82	76	68	60	52	42	32	19
$3\frac{7}{8}$	87	83	78	70	63	55	46	36	25
4	88	84	79	72	66	58	49	40	29
$4\frac{1}{4}$	89	86	81	76	70	63	56	47	37
$4\frac{1}{2}$	90	87	83	79	73	67	61	54	45
$4\frac{3}{4}$	92	89	85	81	76	70	65	58	51
5	93	90	87	83	78	73	67	62	56
$5\frac{1}{2}$	94	92	89	86	82	78	73	68	63
6	95	93	91	88	85	82	78	74	69

TABLE 278.—PERIODS OF ADMISSION, OR POINTS OF CUT-OFF, FOR GIVEN TRAVELS AND LAPS OF SLIDE-VALVES.

Travel of Valve.	Lead of Value.	Periods of Admission, or Points of Cut-off, for the following Laps of Valve, in Inches, in Percentages of Stroke.									
		2	$1\frac{3}{4}$	$1\frac{1}{2}$	$1\frac{1}{4}$	1	$\frac{7}{8}$	$\frac{3}{4}$	$\frac{5}{8}$	$\frac{1}{2}$	$\frac{3}{8}$
Inches.	Inch.	%	%	%	%	%	%	%	%	%	%
12	$\frac{1}{4}$	88	90	93	95	96	97	98	98	99	99
10	$\frac{1}{4}$	82	87	89	92	95	96	97	98	98	99
8	$\frac{1}{4}$	72	78	84	88	92	94	95	96	98	98
6	$\frac{1}{4}$	50	62	71	79	86	89	91	94	96	97
$5\frac{1}{2}$	$\frac{1}{8}$	43	56	68	77	85	88	91	94	96	97
5	$\frac{1}{8}$	32	47	61	72	82	86	89	92	95	97
$4\frac{1}{2}$	$\frac{1}{8}$	14	35	51	66	78	83	87	90	94	96
4	$\frac{1}{8}$	...	17	39	57	72	78	83	88	92	95
$3\frac{1}{2}$	$\frac{1}{8}$	...	...	20	44	63	71	79	84	90	94
3	$\frac{1}{8}$	...	...	...	23	50	61	71	79	86	91
$2\frac{1}{2}$	$\frac{1}{8}$	...	...	...	...	27	43	57	70	80	88
2	$\frac{1}{8}$	...	...	...	..	...	...	33	52	70	81

Woolf Engine:—Continuous Expansion in two Cylinders.

The total work for one stroke of the two pistons, may be calculated by the formula (5), page 504, for the work of a single cylinder.

Receiver Engine:—Successive Expansions in two Cylinders.

The total work for one stroke of the two pistons, may be calculated by the formula:—

$$w = a\,P\left[l'(1 \times \text{hyp. log. } R'') - c\left(1 \times \frac{r-1}{R'}\right)\right] . \qquad . (12)$$

In the construction of the foregoing formulæ, it is assumed that the line of pressure during admission of steam is straight and parallel to the datum-line; that the expansion curves are hyperbolic to the end of the strokes; that the exhaust is open to the end of the return stroke of the second piston; and that there is no back pressure on it.

The work of back pressure is most directly measured from the indicator diagram, in which the other modifications of performance due to compression, and wiredrawing may also be measured.

RULE.—*To find the indicator horse-power of a single-cylinder steam engine, from the indicator diagram.* Multiply the area of the piston in square inches by the effective mean pressure on the piston in pounds per square inch, and by twice the length of the stroke, and by the number of revolutions per minute; and divide the product by 33,000. The quotient is the indicator horse-power.

For compound and multiple-expansion engines, the indicator power in each cylinder is calculated separately; and the sum of the powers thus obtained is the total indicator horse-power. When strokes of the pistons are equal, and if the horse-powers of the cylinders are not required separately, it will suffice to multiply the area of each piston by the effective mean pressure; and to complete the calculation with the sum of these products.

The best performance of steam engines under various conditions, may be accepted approximately to be as follows:—

Single Cylinders, not steam-jacketed, non-condensing.—Steam cut off at one-third of the stroke, and consumed at the rate of 26 pounds per indicator horse-power per hour; the effective pressure during admission being 60 lbs. per square inch.

Single Cylinders, using superheated steam, non-condensing.—With 80 lbs. effective pressure of steam during admission. cutting off at one-fifth; 18½ pounds of steam consumed per indicator horse-power per hour. For a lower effective mean pressure of 34 lbs. per square inch, cutting off at about 30 per cent. with 130 degrees of superheat, about 30½ pounds of steam are consumed per indicator horse-power per hour.

Single Cylinders, steam-jacketed, non-condensing.—With 75 lbs. effective pressure during admission, cutting off at one-fifth, 25 pounds of steam are consumed per indicator horse-power per hour.

Single Cylinders, with superheated steam, condensing.—With 65 lbs. effective pressure during admission, and 150 degrees of superheat, cutting off at 22½ per cent. of the stroke. 15½ pounds of steam are consumed per indicator horse-power per hour.

Single Cylinders, not steam-jacketed, condensing.—The economical results are affected by the length of the stroke relatively to the diameter. In strokes considerably longer than the diameters, an admission of from 15 per cent. to 20 per cent. is most efficient for economy. With initial steam of 80 lbs. total pressure per square inch, approximately 20 pounds of steam are consumed per indicator horse-power per hour.

For short-stroke cylinders—having strokes considerably shorter than two diameters—with initial steam of 73 lbs. total pressure, approximately 25 pounds of steam are consumed per horse-power.

Single Cylinders, steam-jacketed, condensing.—The period of admission most favourable for economy, is from 15 per cent. to 25 per cent. of the stroke. For thoroughly steam-jacketed cylinders, of long strokes, the longer periods of admission are preferable; and for those of short strokes, the shorter periods. For cylinders jacketed only at the sides or barrel, the longer ranges are preferable. With thoroughly steam-jacketed cylinders of long stroke, and steam of 80 lbs. total initial pressure, about 18½ pounds of steam are consumed per indicator horse-power per hour; and for cylinders of short stroke, 21 pounds.

Woolf Compound Steam Engines.

Proportionally long strokes, compared with proportionally short strokes, are conducive to economy. With a stroke of five diameters, and a total initial pressure of 100 lbs. per square inch, and worked with 12 actual expansions, the work is done for about 14 pounds of steam per indicator horse-power per hour. With a stroke equal to twice the diameter, 17½ pounds are consumed.

Receiver Compound Steam Engines.

With a stroke equal to from two to three diameters of the first cylinder, for a total initial pressure of from 80 lbs. to 90 lbs. per square inch, cutting off at one-fifth, and ten actual expansions, with thorough jacketing and intermediate heating of steam, the work may be done with a consumption of 15 pounds of steam per indicator horse-power per hour. With shorter strokes—from 1⅛ to 1½ diameters—18½ pounds are consumed. Without steam-jacketing, the consumption of steam is from 2 pounds to 3 pounds more.

Capacity-ratio of Multiple-Expansion Cylinders.

For speed of piston of from 750 feet to 1000 feet per minute, the capacity-ratios of triple-expansion steam engines, given in the following Table, are recommended. They are based upon a wide range of practice. The terminal absolute pressure of steam in the third cylinder, is supposed to be about 10 lbs. per square inch.

TABLE 279.—TRIPLE - EXPANSION STEAM ENGINES :— CAPACITY-RATIOS OF CYLINDERS RECOMMENDED.

(Jay M. Whitham.)

Gauge Pressure per Square Inch in the Boiler.	Capacity-Ratios of Cylinders.		
	1st (Small).	2nd (Intermediate).	3rd (Large).
Pounds.	Ratio.	Ratio.	Ratio.
130	1	2·25	5·00
140	1	2·40	5·85
150	1	2·55	6·90
160	1	2·70	7·25
170 and upwards	Quadruple expansion to be adopted.		

For quadruple expansion, with steam of, say, 180 lbs. per square inch, capacity-ratios of four cylinders, taken as 1, 2, 4, 8, are very suitable.

Efficiency and Frictional Resistance of Steam Engines.

The frictional resistance of steam engines varies inversely as their leading dimensions. A direct-action engine having a 4-inch cylinder, yielded at the main shaft only 43 per cent. of the indicator power, with a frictional resistance of 57 per cent.

Eight horse-power portable engines, having 9-inch cylinders, yield from 78 per cent. to 87 per cent., with from 13 per cent. to 22 per cent. of resistance.

Corliss engines having 18-inch and 24-inch cylinders, yield about 90 per cent. of the indicator power at the main shaft; with about 10 per cent. of resistance.

Compound engines having first cylinders of from 12 inches to 21 inches in diameter, with or without a beam, yield from 80 per cent. to 89 per cent. of the indicator power.

Rotative pumping steam engines yield from 80 per cent. to 86 per cent. of duty; Worthington's large pumping engines for waterworks, yield 91 per cent. So also do Cornish pumping engines.

From the results of experiments made by Dr. Thurston, on the distribution of friction in direct-acting non-condensing steam engines having balanced valves, it appears that from 40 per cent. to 47 per cent. of the resistance arises at the main bearings; about 33 per cent. at the piston and its rod, 7 per cent. at the crank-pin, 5½ per cent. at the crosshead and gudgeon, 2½ per cent. at the valve and its rod, 5¼ per cent. at the excentric-strap. An unbalanced valve absorbed 26½ per cent. of the whole resistance. In a condensing engine, the air-pump caused 12 per cent. of the resistance.

The frictional resistance of a steam engine increases very slowly with the load. In some cases, the load may be doubled, whilst the resistance is increased by only one-fifth.

Lancashire Steam Boiler—Standard Data.

Boiler of Wrought-iron.—Shell 7 feet in diameter, 27 feet long; two furnace-tubes, 2 feet 9 inches in diameter. Shell plates $\frac{7}{16}$ inch thick for a working steam pressure of 75 lbs. per square inch; $\frac{8}{16}$ inch thick for 100 lbs. pressure. Plates of furnace-tubes, $\frac{3}{8}$ inch and $\frac{7}{16}$ inch respectively.

Fire-grates 6 feet long; fire-bars $\frac{3}{4}$ inch thick; air-spaces between fire-bars, $\frac{3}{8}$ inch wide.

Height of flue-way over each bridge, 14 inches; side flues 6 inches wide at the top; width of bottom flue equal to the semi-diameter of the boiler, or 3½ feet. The draught passes from the furnace-tubes to the bottom flue, thence by the sides to the back.

The grate-area is 16½ square feet for one furnace, or 33 square feet for both furnaces. The air-space through each grate is 5½ square feet, or one-third of the grate-area.

The flue-way over each bridge is 1·88 square feet, or 11½ per cent. of the grate-area—about $\frac{1}{9}$th.

Each furnace-tube has 5·94 square feet of sectional area beyond the bridge = nearly one-third of the grate-area.

The bottom flue has 7 square feet of sectional area, or fully one-fifth of the whole grate-area.

The side flues have a united area of 12½ square feet, or nearly two-fifths of the whole grate-area.

The weight of the boiler is about 12 tons; with fittings, 15½ tons. The cost is about £425, or about £27 8*s*. per ton, or £16 per lineal foot.

The heating surface is 850 square feet, or 26 times the grate-area. The heating surface is augmented by feed-water heaters, occasionally to the extent of three-fourths. In such a boiler, from 15 tons to 20 tons of coal may, without undue stress, be consumed per week of 60 hours, or from 5 cwt. to 6¼ cwt. per hour, or from 17 lbs. to 23 lbs. per square foot of fire-grate per hour. At the rate of 8 pounds of water per pound of coal, this corresponds to an evaporation of from 70 to 90 cubic feet of water per hour.

In the best practice, iron boiler-plates have a tensile strength of from 24 to 25 tons per square inch, with an elongation of from 10 per cent. to 15 per cent.; and steel boiler-plates from 27 to 32 tons, with 30 per cent. of elongation. For a 7-feet boiler, at 80 lbs. pressure, ½ inch iron plates, or ⅜ inch steel plates are used.

The nominal horse-power of Lancashire and Cornish boilers is reckoned at the rate of 6 square feet of the combined horizontal area of the shell and the flues. The horizontal area is the product of the length by the sum of the diameters of the shell and flues. Thus, a Lancashire boiler 27 feet long, 7 feet in diameter, with two furnace-tubes 2¾ feet in diameter, has a horizontal area of $(27 \times (7 + 2\frac{3}{4} + 2\frac{3}{4})) = 337\frac{1}{2}$ square feet: divided by 6, it gives 56 nominal horse-power. The grate-area is ·60 square foot—a little more than half a foot—per horse-power; and there is 15 square feet of heating surface per horse-power.

Factory Chimneys.

The proportions of chimneys vary very much with relation to the requirements. The quantity of good coal that may be consumed per hour with a chimney of a given height above the level of the fire-grates, and a given top-sectional area, and a temperature in the chimney equal to or near to 600° F., under easy conditions, is expressed by the formula :—

$$C = 16A\sqrt{H} \qquad (13)$$

C = coal consumed per hour, in pounds.
A = sectional area of chimney at top, in square feet.
H = height of chimney above the level of the grates, in feet.
G = total area of fire-grates, in square feet.

When the top diameter of the chimney is one-thirtieth of the height—a good proportion—the formula becomes,—

$$C = {\cdot}014\,H^{2{\cdot}5} \qquad (14)$$

$$C = {\cdot}014\,H^2\sqrt{H} \qquad (15)$$

And the total grate-area, allowing a consumption of 15 pounds of coal per square foot per hour, is,—

$$G = \frac{H^2\sqrt{H}}{1071} \qquad (16)$$

$$\text{or } G = \frac{H^{2{\cdot}5}}{1071} \qquad (17)$$

The height of chimney for a given total grate-area, the diameter at the top being equal to one-thirtieth of the height, is,—

$$H = 16{\cdot}3^{2{\cdot}5}\sqrt{G} \qquad (18)$$

The side of a square chimney equal in sectional area to a given round chimney, is equal to the product of the diameter by ·886; and the equivalent fraction of the height for the side of a square chimney is one thirty-fourth.

Conversely, the diameter of a round chimney equal in sectional area to a given square chimney, is equal to the product of the side of the square by 1·13.

In Table 280, are given the quantity of coals that may be consumed per hour, at the assumed rate of 15 pounds per square foot per hour, and the corresponding total area of fire-grate, for chimneys of various heights, and corresponding diameters one-thirtieth of the respective heights.

TABLE 280.—FACTORY CHIMNEYS.

Chimney.			Coal Consumable per Hour.	Grate Area.	Chimney.			Coal Consumable per Hour.	Grate Area.
Height	Diameter.				Height.	Diameter.			
Feet.	Ft.	Ins.	Pounds.	Sq. Ft.	Feet.	Ft.	Ins.	Pounds.	Sq. Ft.
40	1	4	142	9·5	110	3	8	1777	118·4
50	1	8	248	16·5	120	4	0	2208	147·2
60	2	0	390	26·0	135	4	6	2964	197·6
70	2	4	574	38·3	150	5	0	3858	257·2
80	2	8	801	53·4	165	5	6	4896	326·4
90	3	0	1076	71·7	180	6	0	6086	405·7
100	3	4	1394	93·0	200	6	8	7920	526·6

TABLE 281.—HORSE-POWER IN VARIOUS COUNTRIES IN FOOT-POUNDS PER SECOND.

("Steam.")

Country.	Kilogrameters per sec.	Baden per sec.	Saxony per sec.	Würtemberg per sec.
		Foot-lbs.	Foot-lbs.	Foot-lbs.
France and Baden	**75**	**500**	529·68	521·58
Saxony . .	75·045	500·30	**530**	523·89
Würtemberg . .	75·240	501·36	531·12	**525**
Prussia . . .	75·325	502·17	531·97	525·85
Hanover . . .	75·361	502·41	532·23	526·10
England . .	76·041	506·94	537·03	530·84
Austria . . .	76·119	507·46	537·58	531·39

TABLE 281.—HORSE-POWER IN VARIOUS COUNTRIES (*con.*).

Country.	Prussian per sec.	Hanoverian per sec.	English per sec.	Austrian per sec.
	Foot-lbs.	Foot-lbs.	Foot-lbs.	Foot-lbs.
France and Baden	477·93	513·53	542·47	423·68
Saxony . .	478·22	513·84	542·80	423·93
Würtemberg . .	479·23	514·92	543·95	424·83
Prussia . .	**480**	515·75	544·82	425·51
Hanover . . .	480·23	**516**	545·08	425·72
England . .	484·56	520·65	**550**	429·56
Austria . . .	485·06	521·19	550·57	**430**

TABLE 282.—ECONOMY OF FUEL BY HEATING THE FEED-WATER.

(For Steam of 60 lbs. per square inch Working Pressure.)

Initial Temperature of Water.	Final Temperature of Feed-Water (Fahrenheit).						
	120°	140°	160°	180°	200°	250°	300°
° Fahr.	%	%	%	%	%	%	%
32	7·50	9·20	10·90	12·36	14·30	19·03	22·90
35	7·25	8·96	10·66	12·09	14·09	18·34	22·60
40	6·85	8·57	10·28	12·00	13·71	17·99	22·27
45	6·45	8·17	9·90	11·61	13·34	17·64	21·94
50	6·05	7·71	9·50	11·23	13·00	17·28	21·61
55	5·64	7·37	9·06	10·85	12·60	16·93	21·27
60	5·23	6·97	8·72	10·46	12·20	16·58	20·92
65	4·82	6·56	8·32	10·07	11·82	16·20	20·58
70	4·40	6·15	7·91	9·08	11·43	15·83	20·23
75	3·98	5·74	7·50	9·28	11·04	15·46	19·88
80	3·55	5·32	7·09	8·87	10·65	15·08	19·52
85	3·12	4·90	6·63	8·46	10·25	14·70	19·17
90	2·68	4·47	6·26	8·06	9·85	14·32	18·81
95	2·24	4·04	5·84	7·65	9·44	13·94	18·44
100	1·80	3·61	5·42	7·23	9·03	13·55	18·07
110	·90	2·73	4·55	3·38	8·20	12·76	17·28
120	0	1·84	3·67	5·52	7·36	11·95	16·49
130	...	·92	2·77	4·64	6·99	11·14	15·24
140	...	0	1·87	3·75	5·62	10·31	14·99
150	...	...	·94	2·83	4·72	9·46	14·18
160	...	...	0	1·91	3·82	8·59	13·37
170	...	...	...	·96	2·89	7·71	12·54
180	...	...	...	0	1·96	6·81	11·70
190	...	...	...	...	·90	5·90	10·82
200	...	...	...	...	0	4·85	9·93

TABLE 283.—RELATIVE ECONOMY OF FEED-APPARATUS. (Jacobus.)

Feed Water: how Supplied.	Relative Consumption of Coal.	Relative Economy Effected.
Direct-acting pump, feeding water at 60°, without a heater	1·000	0·0
Injector feeding water at 150° without a heater	·985	1·5 per cent.
Injector feeding through a heater in which the water is heated from 150° to 200°	·938	6·2 ,,
Direct-acting pump, feeding water through a heater, in which it is heated from 60° to 200°	·879	12·1 ,,
Geared pump, run from the engine, feeding water through a heater, in which it is heated from 60° to 200°	·868	13·2 ,,

TABLE 284.—WEIGHT OF SEDIMENT COLLECTED IN A STEAM-BOILER, FROM HARD WATER, EVAPORATED AT THE RATE OF 1000 GALLONS PER DAY.

Solid Matter per Gallon Evaporated.	Solid Matter Collected per Day, from 1000 Gallons of Water Evaporated.		Solid Matter Collected per Week of Six Days, from 6000 Gallons of Water Evaporated.		Solid Matter per Gallon Evaporated.	Solid Matter Collected per Day, from 1000 Gallons of Water Evaporated.		Solid Matter Collected per Week of Six Days, from 6000 Gallons of Water Evaporated.	
Grains.	Lbs.	Ozs.	Lbs.	Ozs.	Grains.	Lbs.	Ozs.	Lbs.	Ozs.
1	0	2·3	0	13·7	15	2	2·3	12	13·7
2	0	4·6	1	11·4	20	2	13·7	17	2·3
3	0	6·9	2	9·1	25	3	9·1	21	6·9
4	0	9·1	3	6·9	30	4	4·6	[illegible]	11·4
5	0	11·4	4	4·6	35	5	0	[illegible]	[illegible]
6	0	13·7	5	2·3	40	[illegible]	[illegible]	[illegible]	[illegible]
7	1	0	6	0	45	[illegible]	[illegible]	[illegible]	[illegible]
8	1	2·3	6	13·7	50	[illegible]	[illegible]	[illegible]	[illegible]
9	1	4·6	7	11·4	55	[illegible]	[illegible]	[illegible]	[illegible]
10	1	6·9	8	9·1					

TABLE 285.—MULTIPLIERS FOR FINDING THE EQUIVALENT FOR GIVEN PRESSURES OF STEAM AND

Temperature of Feed Water.	Boiler Pressures in Pounds pe									
	0	5	10	15	20	25	30	35	40	45
° Fahr.										
32	1·187	1·192	1·195	1·199	1·201	1·204	1·206	1·209	1·211	1·212
35	1·184	1·189	1·192	1·196	1·198	1·201	1·203	1·206	1·208	1·209
40	1·179	1·184	1·187	1·191	1·193	1·196	1·198	1·201	1·203	1·204
45	1·173	1·178	1·181	1·185	1·187	1·190	1·192	1·195	1·197	1·198
50	1·168	1·173	1·177	1·180	1·182	1·185	1·187	1·190	1·192	1·193
55	1·163	1·168	1·171	1·175	1·177	1·180	1·182	1·185	1·187	1·188
60	1·158	1·163	1·166	1·170	1·172	1·175	1·177	1·180	1·182	1·183
65	1·153	1·158	1·161	1·165	1·167	1·170	1·172	1·175	1·177	1·178
70	1·148	1·153	1·156	1·160	1·162	1·165	1·167	1·170	1·172	1·173
75	1·143	1·148	1·151	1·155	1·157	1·160	1·162	1·165	1·167	1·168
80	1·137	1·143	1·146	1·149	1·151	1·154	1·156	1·159	1·161	1·162
85	1·132	1·137	1·140	1·144	1·146	1·149	1·151	1·154	1·156	1·157
90	1·127	1·132	1·135	1·139	1·141	1·144	1·146	1·149	1·151	1·152
95	1·122	1·127	1·130	1·134	1·136	1·139	1·141	1·144	1·146	1·147
100	1·117	1·122	1·125	1·129	1·131	1·134	1·136	1·139	1·141	1·142
105	1·111	1·117	1·120	1·123	1·125	1·128	1·130	1·133	1·135	1·136
110	1·106	1·111	1·114	1·118	1·120	1·123	1·125	1·128	1·130	1·131
115	1·101	1·106	1·109	1·113	1·115	1·118	1·120	1·123	1·125	1·126
120	1·096	1·101	1·104	1·108	1·110	1·113	1·115	1·118	1·120	1·121
125	1·091	1·096	1·099	1·103	1·105	1·108	1·110	1·113	1·115	1·116
130	1·085	1·091	1·094	1·097	1·099	1·102	1·104	1·107	1·109	1·110
135	1·080	1·085	1·088	1·092	1·094	1·097	1·099	1·102	1·104	1·105
140	1·075	1·080	1·083	1·087	1·089	1·092	1·094	1·097	1·099	1·100
145	1·070	1·075	1·078	1·082	1·084	1·087	1·089	1·092	1·094	1·095
150	1·065	1·070	1·073	1·077	1·079	1·082	1·084	1·087	1·089	1·090
155	1·059	1·065	1·068	1·071	1·073	1·076	1·078	1·081	1·083	1·084
160	1·054	1·059	1·062	1·066	1·068	1·071	1·073	1·076	1·078	1·079
165	1·049	1·054	1·057	1·061	1·063	1·066	1·068	1·071	1·073	1·074
170	1·044	1·049	1·052	1·056	1·058	1·061	1·063	1·066	1·068	1·069
175	1·039	1·044	1·047	1·051	1·053	1·056	1·058	1·061	1·063	1·064
180	1·033	1·039	1·042	1·045	1·047	1·050	1·052	1·055	1·057	1·058
185	1·028	1·033	1·036	1·040	1·042	1·045	1·047	1·050	1·052	1·053
190	1·023	1·028	1·031	1·035	1·037	1·040	1·042	1·045	1·047	1·048
195	1·018	1·023	1·025	1·030	1·032	1·035	1·037	1·040	1·042	1·043
200	1·013	1·018	1·021	1·025	1·027	1·030	1·032	1·035	1·037	1·038
205	1·008	1·013	1·015	1·020	1·022	1·025	1·027	1·030	1·032	1·033
210	1·008	1·008	1·011	1·015	1·017	1·020	1·022	1·025	1·027	1·028
212	1·002	1·002	...	...	...	...	...	...	...	...

RATE OF EVAPORATION OF WATER FROM AND AT 212° F., TEMPERATURES OF FEED-WATER.

Square Inch above the Atmosphere.										
50	60	70	80	90	100	120	140	160	180	200
1·214	1·217	1·219	1·222	1·224	1·227	1·231	1·234	1·237	1·239	1·241
1·211	1·214	1·216	1·219	1·221	1·224	1·228	1·231	1·234	1·236	1·238
1·206	1·209	1·211	1·214	1·216	1·219	1·223	1·226	1·229	1·231	1·233
1·200	1·203	1·205	1·208	1·210	1·213	1·217	1·220	1·223	1·225	1·227
1·195	1·198	1·200	1·203	1·205	1·208	1·212	1·215	1·218	1·220	1·222
1·190	1·193	1·195	1·198	1·200	1·203	1·207	1·210	1·213	1·215	1·217
1·185	1·188	1·190	1·193	1·195	1·198	1·202	1·205	1·208	1·210	1·212
1·180	1·183	1·185	1·188	1·190	1·193	1·197	1·200	1·203	1·205	1·207
1·175	1·178	1·180	1·183	1·185	1·188	1·192	1·195	1·198	1·200	1·202
1·170	1·173	1·175	1·178	1·180	1·183	1·187	1·190	1·193	1·195	1·197
1·164	1·167	1·169	1·172	1·174	1·177	1·181	1·184	1·187	1·189	1·191
1·159	1·162	1·164	1·167	1·169	1·172	1·176	1·179	1·182	1·184	1·186
1·154	1·157	1·159	1·162	1·164	1·167	1·171	1·174	1·177	1·179	1·181
1·149	1·152	1·154	1·157	1·159	1·162	1·166	1·169	1·172	1·174	1·176
1·144	1·147	1·149	1·152	1·154	1·157	1·161	1·164	1·167	1·169	1·171
1·133	1·141	1·143	1·146	1·148	1·151	1·155	1·158	1·161	1·163	1·165
1·133	1·136	1·138	1·141	1·143	1·146	1·150	1·153	1·156	1·158	1·160
1·128	1·131	1·133	1·136	1·138	1·141	1·145	1·148	1·151	1·153	1·155
1·123	1·126	1·128	1·131	1·133	1·136	1·140	1·143	1·146	1·148	1·150
1·118	1·121	1·123	1·126	1·128	1·131	1·135	1·138	1·141	1·143	1·145
1·112	1·115	1·117	1·120	1·122	1·125	1·129	1·132	1·135	1·137	1·139
1·107	1·110	1·112	1·115	1·117	1·120	1·124	1·127	1·130	1·132	1·134
1·102	1·105	1·107	1·110	1·112	1·115	1·119	1·122	1·125	1·127	1·129
1·097	1·100	1·102	1·105	1·107	1·110	1·114	1·117	1·120	1·122	1·124
1·092	1·095	1·097	1·100	1·102	1·105	1·109	1·112	1·115	1·117	1·119
1·086	1·089	1·091	1·094	1·096	1·099	1·103	1·106	1·109	1·111	1·113
1·081	1·084	1·086	1·089	1·091	1·094	1·098	1·101	1·104	1·106	1·108
1·076	1·079	1·081	1·084	1·086	1·089	1·093	1·096	1·099	1·101	1·103
1·071	1·074	1·076	1·079	1·081	1·084	1·088	1·091	1·094	1·096	1·098
1·066	1·069	1·071	1·074	1·076	1·079	1·083	1·086	1·089	1·091	1·093
1·060	1·063	1·065	1·068	1·070	1·073	1·077	1·080	1·083	1·085	1·087
1·055	1·058	1·060	1·063	1·065	1·068	1·072	1·075	1·078	1·080	1·082
1·050	1·053	1·055	1·058	1·060	1·063	1·067	1·070	1·073	1·075	1·077
1·045	1·048	1·050	1·053	1·055	1·058	1·062	1·065	1·068	1·070	1·072
1·040	1·043	1·045	1·048	1·050	1·053	1·057	1·060	1·063	1·065	1·067
1·035	1·038	1·040	1·043	1·045	1·048	1·052	1·055	1·058	1·060	1·062
1·030	1·033	1·035	1·038	1·040	1·043	1·047	1·050	1·053	1·055	1·057
...	...	...	...	...	...	...	...	...	...	...

Flow of Steam through Pipes.

TABLE 286.—FLOW OF STEAM THROUGH PIPES.
("Steam.")

Initial Pressure per Square Inch.	Diameter of Pipe in Inches. Length of each Pipe, 240 Diameters.						
	¾	1	1½	2	2½	3	4
	Weight of Steam per Minute in Pounds, with One Pound Fall of Pressure.						
Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
1	1·16	2·07	5·7	10·27	15·45	25·38	46·85
10	1·44	2·57	7·1	12·72	19·15	31·45	48·05
20	1·70	3·02	8·3	14·94	22·49	36·94	68·20
30	1·91	3·40	9·4	16·84	25·35	41·63	76·84
40	2·10	3·74	10·3	18·51	27·87	45·77	84·49
50	2·27	4·04	11·2	20·01	30·13	49·48	91·34
60	2·43	4·32	11·9	21·38	32·19	52·87	97·60
70	2·57	4·58	12·6	22·65	34·10	56·00	103·37
80	2·71	4·82	13·3	23·82	35·87	58·91	108·74
90	2·83	5·04	13·9	24·92	37·52	61·62	113·74
100	2·95	5·25	14·5	25·96	39·07	64·18	118·47
120	3·16	5·63	15·5	27·85	41·93	68·87	127·12
150	3·45	6·14	17·0	30·37	45·72	75·09	138·61

Initial Pressure per Square Inch.	Diameter of Pipe in Inches. Length of each Pipe, 240 Diameters.						
	5	6	8	10	12	15	18
	Weight of Steam per Minute in Pounds, with One Pound Fall of Pressure.						
Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
1	77·3	115·9	211·4	341·1	502·4	804	1177
10	95·8	143·6	262·0	422·7	622·5	996	1458
20	112·6	168·7	307·8	496·5	731·3	1170	1713
30	126·9	190·1	346·8	559·5	824·1	1318	1930
40	139·5	209·0	381·3	615·3	906·0	1450	2122
50	150·8	226·0	412·2	665·0	979·5	1567	2294
60	161·1	241·5	440·5	710·6	1046·7	1675	2451
70	170·7	255·8	466·5	752·7	1108·5	1774	2596
80	179·5	269·0	490·7	791·7	1166·1	1866	2731
90	187·8	281·4	513·3	828·1	1219·8	1951	2856
100	195·6	293·1	534·6	862·6	1270·1	2032	2975
120	209·9	314·5	573·7	925·6	1363·3	2181	3193
150	228·8	343·0	625·5	009·2	1486·5	2378	3481

Mr. Babcock gives the following formula for the flow of steam through pipes :—

$$W = 300\sqrt{\frac{D(p_1 - p_2)d^5}{L\left(1 + \frac{3\cdot6}{d}\right)}} \qquad (19)$$

W = weight of steam in pounds.
d = diameter of pipe in inches.
D = density or weight per cubic foot of the steam.
p_1 = initial pressure.
p_2 = pressure at end of pipe.
L = length of pipe in feet.

The Table 286 gives, approximately, the weight of steam which would flow through a straight smooth pipe, of which the length is equal to 240 diameters, with one pound fall of pressure.

For any other given fall of pressure, multiply the tabular weight by the square root of the given fall of pressure.

For any other given length of pipe, divide 240 by the given length in diameters, and multiply the tabular values by the square root of the quotient, to give the flow for one pound fall of pressure.

Conversely, divide the given length by 240, to find the fall of pressure for the flow given in the Table.

The loss of head due to generation of the velocity of flow, and the friction of the steam entering the pipe, is about equal to the resistance of a length of pipe equal to the quotient of 114 diameters, divided by $\left(1 + \frac{3\cdot6}{d}\right)$, in which d is the diameter in inches. For the sizes given in the Table, the corresponding lengths are as follows :—

Diameter in Inches.	Length in Diameters.	Diameter in Inches.	Length in Diameters.	Diameter in Inches.	Length in Diameters.
¾	20	3	52	10	84
1	25	4	60	12	88
1½	34	5	66	15	92
2	41	6	71	18	95
2½	47	8	79		

The resistance of a globe-valve is equal to that at the entrance of the pipe; and that at an elbow is equal to two-thirds of that of a globe-valve. The equivalent lengths respectively are to be added to the actual length of the pipe. For instance, a 4-inch pipe 120 diameters, or 40 feet, long, with a globe-valve and three elbows, would be equivalent to (120 + 60 (entrance) + 60 (globe-valve) + (40 × 3) =) 360 diameters in length. By the rule above given, (360 ÷ 240 =) $1\frac{1}{2}$ lbs. is the fall or loss of pressure for the tabulated flow. Or, it would deliver $(1 \div \sqrt{1\frac{1}{2}} =)$ ·816, or 81·6 per cent. of the steam with the same loss (1 lb.) of pressure.

Coverings for Steam-Boilers and Steam-Pipes.

The efficiency of different substances for the prevention of radiation of heat, varies generally in the inverse ratio of their conducting power for heat. From the results of experiments, it appears that the rates of condensations of steam in a naked pipe, a pipe coated with a cement, and a pipe coated with hair-felt, were proportionally as 100, 67, and 27. According to Dr. Emery, the relative efficiency of various substances as coatings, is as given in Table 287.

TABLE 287.—RELATIVE EFFICIENCY OF NON-CONDUCTORS. (Emery.)

Substance.	Relative Efficiency.
Wood felt	1·000
Mineral wool, No. 2	·832
,, ,, with tax	·715
Sawdust	·680
Mineral wool, No. 1	·676
Charcoal	·632
Pine wood, across fibre	·553
Loam, dry and open	·550
Slacked lime	·480
Gas-house carbon	·470
Asbestos	·363
Coal ashes	·345
Coke in lumps	·277
Air space undivided	·136

The relative loss of heat from steam-pipes naked and clothed with wool or hair-felt, in several thicknesses, is given in Table 287. The steam pressure is taken at 75 lbs. per square inch; and the temperature of the air at 60° F. The horse-power mentioned in the Table is the standard for steam-boilers favourably received in America, according to which one horse-power is measured by the evaporation of 30 pounds of water per hour, at a working pressure of 70 lbs. per square inch from 100° F. temperature.

TABLE 288.—LOSS OF STEAM BY CONDENSATION IN PIPES.

("Steam.")

Thickness of Covering.	OUTSIDE DIAMETER OF PIPE.														
	Two Inches.			Four Inches.			Six Inches.			Eight Inches.			Twelve Inches.		
	Loss per Lineal Foot per Hour.	Ratio of Loss.	Length of Pipe per H. P. Lost.	Loss per Lineal Foot per Hour.	Ratio of Loss.	Length of Pipe per H. P. Lost.	Loss per Lineal Foot per Hour.	Ratio of Loss.	Length of Pipe per H. P. Lost.	Loss per Lineal Foot per Hour.	Ratio of Loss.	Length of Pipe per H. P. Lost.	Loss per Lineal Foot per Hour.	Ratio of Loss.	Length of Pipe per H. P. Lost.
Inches.	Units.		Feet.	Units.		Feet.	Units.		Feet.	Units.		Feet.	Units.		Feet.
Naked.	219·0	1·00	132	390·8	1·00	75	624·1	1·000	46	729·8	1·000	40	1077·4	1·000	26
¼	100·7	·46	288	180·9	·46	160	...	...	...	...	...	...	...	...	...
½	65·7	·30	441	117·2	·30	247	187·2	·300	154	219·6	·301	132	301·7	·280	92
1	43·8	·20	662	73·9	·18	392	111·0	·178	261	128·3	·176	225	185·3	·172	157
2	28·4	13	1020	44·7	·11	648	66·2	·106	438	75·2	·103	385	98·0	·091	294
4	19·8	·09	1464	28·1	·07	1031	41·2	·066	703	46·0	·063	630	60·3	·056	486
6	...	...	...	23·4	·06	1238	33·7	·054	860	34·8	·047	845	45·2	·042	642

RAILWAYS.

THE lengths of lines in the United Kingdom open for traffic on the 31st December, 1889, were in—

	Miles Open.
England and Wales	14,034
Scotland	3,118
Ireland	2,791
	19,943

or, as a round number, say, 20,000 miles.

The total paid-up capital, including loans and debenture stock, was £876,595,166, or £43,960 per mile open.

The number of passengers conveyed in the year 1889, were :—

1st class	30,074,810	or	3·88	per cent.
2nd „	62,687,927	„	8·07	„
3rd „	682,420,336	„	88·05	„
Total	775,183,073		100·00	

In goods traffic there were conveyed—

211,810,551 tons of minerals, or	71·20	per cent.
85,695,947 „ „ general merchandise	28·80	„
297,506,498	100·00	

The number of miles travelled by trains were as follows :—

	Miles.
Passenger trains	161,082,875
Goods and mineral trains	138,941,233
Total	303,116,953

The total includes 3,092,845 miles travelled by mixed trains.

The receipts were as follows :—

Gross receipts from passenger traffic	£32,630,724	or	42·4	per cent.
Do. Goods „	41,086,333	„	53·3	„
Miscellaneous receipts	3,307,960	„	4·3	„
	£77,025,017		100·0	

or about £3,851 per mile open, or 5*s*. 1*d*. per train-mile run.

The total working expenditure was £40,094,116, or 52 per cent. of the receipts.

The rolling stock, on December 31, 1889, was as follows:—

Locomotives (fully three-fourths of a locomotive per mile open) . . .	15,924
Passenger carriages	36,137
Other passenger train stock . . .	13,501
Waggons	503,260
Sundry carriages and waggons . . .	14,335
Passenger and goods trains carrying stock (or about $35\frac{1}{2}$ vehicles per locomotive; or about $28\frac{3}{4}$ vehicles per mile open)	567,233

The average number of train-miles run per locomotive was 19,000.

The standard forms of rails are the bull-headed, the double-headed, and the flange or flat-foot rails. Of the rails used on British and Irish railways, the following are the principal dimensions:—

TABLE 289.—RAILWAY RAILS AND SLEEPERS.

	Bull-headed Rails.	Double-headed Rails.	Flange Rails.
Weight of rail per yard .	80 lb. to 86 lb.	82 lbs.	74 lbs., 79 lbs.
Height . .	$5\frac{3}{16}$ ins. to $5\frac{5}{8}$ ins.	$5\frac{1}{4}$ ins., $5\frac{3}{8}$ ins.	$4\frac{9}{16}$ ins. to $4\frac{15}{16}$ ins.
Width of head .	$2\frac{1}{2}$ ins. to $2\frac{3}{4}$ ins.	$2\frac{1}{2}$ ins.	$2\frac{1}{2}$ ins., $2\frac{3}{8}$ ins.
Width of flange	...	...	5 ins.
Thickness of web	$\frac{11}{16}$ in. to $\frac{13}{16}$ in.	$\frac{11}{16}$ in. to $\frac{7}{8}$ in.	$\frac{9}{16}$ in. to 1 in.
Length of bars .	24 ft. to 32 ft.	24 ft. to 30 ft.	24 ft. to $26\frac{1}{2}$ ft.
Section of sleepers	10×5 ft. to 12×6 ft.	10×5 ft.	10×5 ft.
Distance of sleepers apart	2 ft. 6 ins. to 3 ft. 1 in.	2 ft. 8 in. to 2 ft. 10 in.	3 ft.
Weight of chair	39 lbs. to 55 lbs.	31 lbs. to 40 lbs.	...

Large express locomotives weigh in working order from 40 tons to 50 tons. The latest Midland Railway express engine weighs, in working order, 43 tons, of which the driving weight, on a single pair of wheels, is $17\frac{1}{2}$ tons. The area of fire-grate is 19·6 square feet; the heating surface is $1,240\frac{1}{2}$

square feet. The tender weighs, empty, 12 tons; and 30 tons when loaded with 3½ tons of coal, and 3,250 gallons of water. The working steam pressure in the boiler is 160 lbs. per square inch. The cylinders are 18½ inches in diameter, with a stroke of 26 inches. The driving wheels, single, are 7½ feet in diameter, with a bogie in front. The total wheel-base of the engine and tender together is about 43 feet on the rails. On the London and Nottingham traffic, the average gross load weighs from 170 to 215 tons, or from 9 to 12 carriages. The time-bill speed is 53½ miles per hour; the longest continuous run is 124 miles, and from 20 lbs. to 23 lbs. of Derbyshire coal is consumed per mile-run.

Parliamentary trains, calling at all the stations, run at an average speed of from 19 to 28 miles per hour. Express goods trains make a speed of from 20 to 25 miles per hour. The speed of coal trains is limited, as far as is practicable, to 15 miles per hour.

Coal trains generally consist of from 30 to 35 waggons, weighing from 5 tons to 5½ tons each, and carrying 8 tons of coal. At this rate, the total load of coal for 35 waggons weighs 280 tons; add the weight of the break van at the end of the train, 10 tons, 17 cwt., and the maximum gross weight of the train is 483 tons, 7 cwt.

A 6-coupled locomotive, suited for taking this train on the Great Northern Railway, has 5½ feet wheels, 17½ inch cylinders with a 26 inch stroke, with 140 lbs. pressure in the boiler; weighing, in working order, 37 tons, and with the tender full of water and coal, 68 tons. The engine, tender, and train together weigh 551 tons. Such trains are taken at a speed of 18 miles per hour; ascending inclines of 1 in 178 at a speed of 10 miles per hour; consuming 45 lbs. of coal per mile. With more powerful engines, having 19 inch cylinders, trains of 45 loaded coal waggons are taken.

Six-coupled goods engines, working at full power, exert a tractive force of from 5 tons to 6 tons at the rails. With a tractive force of 10 lbs. or 12 lbs., 1 ton of gross weight can be drawn on a level straight line at a speed of 10 miles per hour. At 60 miles per hour, the tractive force, with sharp curves and high winds, may amount to 45 lbs. for 1 ton.

Railway Gauges.

The standard gauge of railways in Great Britain is 4 feet 8½ inches. The same gauge is adopted in some other countries. See Table 290.

TABLE 290.—GAUGES OF THE PRINCIPAL RAILWAY SYSTEMS IN THE WORLD.

	Ft.	Ins.
Great Britain, standard gauge	4	8½
Ireland, standard gauge	5	3
Central Europe, prevailing gauge	4	8½
Russia, standard gauge	5	0
Norway	4	8½
	3	6
Spain and Portugal, standard gauge	5	6
Antwerp and Ghent	2	3
India, prevailing gauge	5	6
„ metre gauge	3	3⅜
„ Arconum and Conjeveram	3	6
Japan	3	6
Egypt	4	8½
Canada	5	6
	4	8½
	3	6
Mexico	4	8½
	3	0
United States of America prevailing gauges	4	8½
	4	9
	6	0
	5	0
	3	0
	2	0
Chili	5	6
	4	8½
	4	2
	3	6
Brazil	5	6
	5	3
South Australia	5	3
	3	6
New South Wales	4	8½
Victoria	5	3
New Zealand	5	3
	3	6

In the United Kingdom there are a few local railways of less than the national gauge:—

	Feet.	Inches.
Festiniog	1	11½
Talyllyn	2	6
Dinas and Snowdon, Ballymena and Larne, and others	3	0

The Way: Rails, Chairs, and Sleepers.

The bull-headed rail is laid on most of the railways in Great Britain. The double-headed rail, reversible, is also in use. In Ireland, both are in use. They weigh from 82 lbs. to 86 lbs. per lineal yard. The heads are from 2½ to 2¾ inches wide; and the height of rail is from 5¼ to 5⅝ inches. The rails are of steel, rolled in bars mostly 30 feet in length. They are carried in cast-iron chairs weighing from 31 lbs. to 55 lbs. each, spiked to transverse sleepers of Baltic red wood generally 10 inches wide, 5 inches deep, and 9 feet long.

Cost of 1 *Mile of Single Line of Way on a first class Railway.*

	£	*s.*	*d.*
Steel rails, bull-headed, 30 feet long, 85 lbs. per yard; 133½ tons at £5	667	10	0
Chairs, 3,872, at 50 lbs.; 86½ tons at £3	259	10	0
Fish-plates, steel clip, 352 pairs at 40 lbs. = 6¼ tons, at £8	50	0	0
Bolts and nuts, 1,408 at 1½ lbs.; 1 ton at £9 10*s.*	9	10	0
Spikes, 7,744 at 1¼ lbs.; 4¼ tons at £7 10*s.*	31	17	6
Trenails, solid oak, 7,744 at £2 10*s.* per 1,000	19	7	2
Keys, oak, 3,872 at £4 per 1,000	15	9	9
Sleepers, creosoted, 1,936 at 4*s.*	387	4	0
Labour, 1,760 yards at 1*s.* 6*d.*	132	0	0
Total cost of laying	£1,572	8	5
Taking credit for old materials in case of relaying, the net cost of relaying is, say	£858	0	2

To find the position of the Centre of Gravity of a locomotive in the horizontal sense, when the loads on the rails at the axle, and their distances apart are given.

1. *Four-wheeled locomotive.* Multiply the load at the driving axle in tons by the length of the wheel-base in feet;

and divide by the total weight in tons. The quotient is the horizontal distance, in feet, of the centre of gravity from the other axle.

When the loads at the axles are equal, the centre of gravity lies half-way between them.

2. *Six-wheeled locomotive.* Multiply the loads at the leading and trailing axles, in tons, by their respective distances from the middle axle in feet; divide the difference of the products so found by the total weight in tons. The quotient is the horizontal distance, in feet, of the centre of gravity from the middle axle, measured towards the axle for which the greater product was found.

When the products are equal, the centre of gravity lies exactly over the middle axle.

3. *Locomotives having more than six wheels.* Select a middle axle. Multiply the loads at the axles in front of the selected axle by their distances respectively from this axle; do likewise with the axles behind the selected axle. Find the difference of the sums of the products in front and behind the selected axle; and divide it by the total weight in tons. The quotient is the distance horizontally, in feet, of the centre of gravity from the selected axle, measured in the direction for which the greater sum of the products was found.

Tractive Power and Resistance on Railways.

For two cylinders of equal diameters, the equivalent tractive force, as at the rails for a given effective mean pressure in the cylinders, may be calculated by means of the formula—

$$T = \frac{d^2 L p}{D} \qquad . \quad . \quad . \quad . \quad . \quad (1)$$

The equivalent effective mean pressure in the cylinders required for a given tractive force as at the rails is by formula—

$$p = \frac{DT}{d^2 L} \qquad . \quad . \quad . \quad . \quad . \quad (2)$$

d = diameter of cylinder, in inches.
L = length of stroke, in inches.
D = diameter of driving wheels, in inches.
p = effective mean pressure, in pounds per square inch.
T = equivalent tractive force, as at the rails, in pounds.

If it be assumed that the work done in the second cylinder of a compound locomotive is equal to that done in the first cylinder, the formula (1) becomes available for calculating the tractive force at the rails in terms of the sizes and pressure of the first cylinder.

The proportion of the adhesion weight, or driving weight, varies from one-fifth in dry weather to one-ninth in damp weather. A fraction of from one-sixth to one-seventh may be adopted in calculation, as it can be maintained by the use of sand on the rails or other expedients. The fraction 1-6·4th gives an adhesion of 350 pounds per ton; and adopting this unit, the adhesions for various driving weights are as follows:—

Driving Weight in tons.	Adhesion or available tractive force as at the rails.	
10	3,500 pounds, or	1·56 tons.
20	7,000 „ „	3·12 „
30	10,500 „ „	4·68 „
40	14,000 „ „	6·25 „
50	17,500 „ „	7·81 „
60	21,000 „ „	9·37 „

The resistance of engines and trains on railways is expressed by the formula (3), quoted from *Railway Machinery.* It applies under the following conditions:—

1. The permanent way in good order.

2. The engine, tender, and train in good order; lubricated with grease.

3. A straight and level line of rails.

4. Fair weather, and dry and clean rails.

5. An average side-wind, of average force, varying during the experiment between *slight* and *very strong.*

Resistance of Engine, Tender, and Train.

$$R = 8 + \frac{V^2}{171} \quad . \quad . \quad . \quad . \quad (3)$$

V = speed in miles per hour.
R = total resistance in pounds per ton.

In cases of frequent sharp curves, in connection with strong ide and head winds, the resistance may be augmented by one-alf the given resistance on a level.

The annexed Table 291, gives the resistance per ton of gine, tender, and train, for various speeds and gradients.

TABLE 291.—RESISTANCE OF PASSENGER TRAINS.

Ascending Gradients.	CONDITIONS. A good sound road. A straight line. An average side-wind. Engine, tender, and train in good working order, with grease lubrication.						
	Speed, in Miles per Hour.						
	10	20	30	40	50	60	70
	Total Resistance as at the Rails, in Pounds per Ton.						
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Level	8·6	10·3	13·2	17·3	22·6	29	36·6
1 in 40	64	66	69	73	79	85	93
1 „ 60	46	48	50	55	60	66	74
1 „ 80	36	38	41	45	51	57	65
1 „ 100	31	33	36	40	45	51	59
1 „ 150	24	26	28	32	38	44	51
1 „ 200	20	22	25	29	34	40	48
1 „ 250	18	20	22	26	32	38	46
1 „ 300	16	18	21	25	30	36	44
1 „ 500	13	15	18	22	27	33	41
1 „ 800	11	13	16	20	25	32	39
1 „ 1000	11	12	15	19	25	30	39
Level	8·6	10·3	13·2	17·3	22·6	29	36·6

Note.—Fifty per cent. of the resistance as on a straight level way may be added for cases of frequent curves, of or under one mile in radius, in connection with strong side and head winds.

The general dimensions, weights, and capacity of the standard carriage stock and waggon stock of the Midland Railway, are given in Tables 295 and 296, page 543.

Supposing an engine and tender, weighing together 40 tons, and exerting a given tractive force, takes 40 loaded carriages, weighing 360 tons, at 20 miles per hour on a level, the loads which it could take if it exerted the same tractive force at higher speeds, would be proportionately as follows :—

At 20 miles per hour, 40 carriages weighing 360 tons.
„ 30 „ „ 30 „ „ 200 „
„ 40 „ „ 21 „ „ 144 „
„ 50 „ „ 15 „ „ 106 „
„ 60 „ „ 11 „ „ 75 „

The influence of rising inclines is exemplified as follows :—

If an engine and tender, weighing together 40 tons, can draw a maximum train of 42 loaded carriages, weighing 420 tons, at 20 miles per hour on a level, it would draw only the following loads at the same speed up the annexed inclines :—

Level		. . .	42	carriages,	weighing	420	tons.
Incline, 1 in	600	.	34	”	”	340	”
” ”	300	.	27	”	”	270	”
” ”	150	.	20	”	”	200	”
” ”	100	.	15	”	”	150	”
” ”	75	.	12	”	”	120	”
” ”	50	.	9	”	”	90	”
” ”	40	.	6	”	”	65	”
” ”	30	.	5	”	”	45	”
” ”	20	.	3	”	”	24	”
” ”	10	.	nil	”	”	nil.	

The speed of railway trains may be calculated in terms of the number of revolutions of the driving wheels of the locomotive in a given number of seconds. Let,—

r = number of revolutions in the given time.
t = time in seconds.
d = diameter of driving wheels, in feet.
v = velocity or speed in miles per hour.

The number of turns per hour is $\left(r \times \frac{60}{t} \times 60 \text{ minutes}, = \right)$

$$\frac{3{,}600\, r}{t} \quad . \quad . \quad . \quad . \quad . \quad (a)$$

The number of turns per mile is $\left(\frac{5{,}280 \text{ feet}}{3 \cdot 1416\, d} = \right)$

$$\frac{1680 \cdot 7}{d} \quad . \quad . \quad . \quad . \quad . \quad (b)$$

The speed in miles per hour is equal to (*a*) divided by (*b*); or, by reduction,—

$$v = \frac{2 \cdot 142\, d\, r}{t} \quad . \quad . \quad . \quad (4)$$

The Table 292 gives multipliers in the 3rd column, by the use of which the speed of a train may be calculated in terms of the diameter of the driving wheel, column 1, for any given number of revolutions of the wheels in a given number of seconds. The speeds in the 3rd column are those due to one revolution in one second; and the speed due to the given diameter of wheel is to be multiplied by the observed number of turns, and the product divided by the time of observation in seconds. Or, thus,—

$$\text{Speed for 1 turn in 1 second} \times \frac{\text{number of turns observed}}{\text{time of observation in seconds}}.$$

For example, a 5 feet driving wheel makes 20 revolutions in 10 seconds. The multiplier in the 3rd column for a 5-feet wheel is 10·71; and the speed is $\left(10{\cdot}71 \times \frac{20}{10} = \right)$ 21·42 miles per hour.

TABLE 292.—MULTIPLIERS FOR SPEED OF RAILWAY TRAINS.

Diameter of Driving Wheels. 1. Ft.	Ins.	Number of Revolutions in One Mile. 2. Revolutions.	Speed for One Revolution in One Second. 3. Miles per Hour.	Diameter of Driving Wheels. 1. Ft.	Ins.	Number of Revolutions in One Mile. 2. Revolutions.	Speed for One Revolution in One Second. 3. Miles per Hour.
3	0	560·2	6·42	6	9	249·0	14·46
3	3	517·1	6·96	7	0	240·1	14·99
3	6	480·2	7·50	7	3	231·8	15·53
3	9	448·2	8·03	7	6	224·1	16·06
4	0	420·2	8·57	7	9	216·9	16·60
4	3	395·4	9·10	8	0	210·1	17·14
4	6	373·5	9·64	8	3	203·7	17·67
4	9	353·8	10·17	8	6	197·7	18·21
5	0	336·1	10·71	8	9	192·7	18·74
5	3	320·1	11·25	9	0	186·7	19·28
5	6	305·6	11·78	9	3	181·7	19·81
5	9	292·3	12·32	9	6	176·9	20·35
6	0	280·1	12·85	9	9	172·4	20·88
6	3	268·9	13·39	10	0	168·1	21·42
6	6	258·6	13·92				

The relations of the speed in miles per hour and the corresponding time running one mile, are expressed by the formulas (5) and (6). There are (60 × 60 =) 3,600 seconds in an hour, and the time of running one mile is equal to the quotient of 3,600 divided by the speed in miles per hour. Also the speed is equal to the quotient of 3,600 divided by the time of running one mile. Or,

$$t = \frac{3{,}600}{v} \quad . \quad . \quad . \quad . \quad (5)$$

$$v = \frac{3{,}600}{t} \quad . \quad . \quad . \quad . \quad (6)$$

t = time running one mile, in seconds.
v = speed in miles per hour.

By means of formula (5), the Table 293 has been calculated.

TABLE 293.—SPEED IN MILES PER HOUR, AND CORRESPONDING TIME RUNNING ONE MILE.

Speed in Miles per Hour.	Time Running One Mile.			Speed in Miles per Hour.	Time Running One Mile.		
Miles.	Seconds.	Mins.	Secs.	Miles.	Seconds.	Mins.	Secs.
1	3600	60	0	29	124	2	4
1½	2400	40	0	30	120	2	0
2	1800	30	0	31	116	1	56
2½	1440	24	0	32	112	1	52
3	1200	20	0	33	109	1	49
3½	1028	17	8	34	106	1	46
4	900	15	0	35	103	1	43
4½	800	13	20	36	100	1	40
5	720	12	0	37	97	1	37
6	600	10	0	38	95	1	35
7	514	8	34	39	92	1	32
8	450	7	30	40	90	1	30
9	400	6	40	41	88	1	28
10	360	6	0	42	86	1	26
11	327	5	27	43	84	1	24
12	300	5	0	44	82	1	22
13	277	4	37	45	80	1	20
14	257	4	17	46	79	1	19
15	240	4	0	47	77	1	17
16	225	3	45	48	75	1	15
17	212	3	32	49	73	1	13
18	200	3	20	50	72	1	12
19	190	3	10	51	71	1	11
20	180	3	0	52	70	1	10
21	171	2	51	53	68	1	8
22	164	2	44	54	67	1	7
23	157	2	37	55	65	1	5
24	150	2	30	56	64	1	4
25	144	2	24	57	63	1	3
26	138	2	18	58	62	1	2
27	133	2	13	59	61	1	1
28	129	2	9	60	60	1	0

(Continued on next page.)

Table 293.—Speed in Miles per Hour (*continued*).

Speed in Miles per Hour.	Time Running One Mile.	Speed in Miles per Hour.	Time Running One Mile.	Speed in Miles per Hour.	Time Running One Mile.
Miles.	Seconds.	Miles.	Seconds.	Miles.	Seconds.
61	59	75	48	88	41
62	58	76	47·4	89	40·4
63	57	77	47	90	40
64	56	78	46	91	39·6
65	55	79	45·6	92	39·1
66	54·5	80	45	93	38·7
67	54	81	44·4	94	38·3
68	53	82	44	95	37·9
69	52	83	43·4	96	37·5
70	51·4	84	43	97	37·1
71	51	85	42	98	36·7
72	50	86	41·9	99	36·4
73	49	87	41·4	100	36
74	48·6				

Table 294.—Bulk and Weight of Goods, as conveyed by Railway.

(Col. Kennedy.)

Number of Kind of Goods.	Description of Goods carried.	Cubic Feet per Ton.	Weight per Cubic Foot.
No.		Cubic Feet.	Pounds.
	Class 1.		
1	Unpressed Cotton . . .	224	10
2	Furniture	200	11
3	Half-pressed cotton . .	186	12
4	Cotton seeds	186	12
5	Wool	140	16
6	Fruit and vegetables . . .	100	22
7	Eggs	90	25
	Class 2.		
8	Grass	80	28
9	Sundries	80	28
10	Bagging	70	32
11	Commissariat stores . .	70	32

TABLE 294.—BULK AND WEIGHT OF GOODS (*continued*).

Number of Kind of Goods.	Description of Goods carried.	Cubic Feet per Ton.	Weight per Cubic Foot.
No.		Cubic Feet.	Pounds.
	CLASS 2 (*continued*).		
12	Full-pressed cotton	70	32
13	Flax and hemp	70	32
14	Groceries	60	37
15	Grains and seed	60	37
16	Twist	60	37
17	Sugar	56	40
18	Soap	56	40
19	Firewood	56	40
20	Salt	51	44
21	Lime	51	44
22	Dry fruits	50	45
	CLASS 3.		
23	Molasses	45	50
24	Seed cotton	45	50
25	Mowra (flowers which produce spirit)	45	50
26	Timber	45	50
27	Ghee (clarified butter)	40	56
28	Oil	40	56
29	Piece goods	40	56
30	Rape	40	56
31	Beer and spirits	36	62
32	Coal	28	80
33	Paper	28	80
34	Tobacco	28	80
35	Opium	26	86
36	Machinery	25	90
	CLASS 4.		
37	Cutlery	20	112
38	Potash	20	112
39	Sand	20	112
40	Colours	18	124
41	Bricks	17	132
42	Stone	15	148
43	Metal	5	448

TABLE 295.—CARRIAGE STOCK, MIDLAND RAILWAY.

Carriage.	Length of Body.	Compartments.	Number of Passengers.	Weight of Vehicle.	Price.
	Ft.			Tons. Cwts.	£
6-wheel bogie composite . . .	54	3 first class, 4 third class, 1 luggage = 8	58	23 0	1007
4-wheel bogie composite . . .	45	3 first class, 3 third class, 1 luggage = 6	48	18 10	768
4-wheel bogie, third class . . .	43	7 third class . .	70	17 15	620
4-wheel bogie composite . . .	40	2 first class, 3 third class, 1 luggage = 6	42	17 5	654
6-wheel first class .	30	4 first class	24	10 13	516
6-wheel composite .	31	2 first class, 2 third class, 1 luggage = 5	32	11 10	450
6-wheel third class .	31	5 third class . .	50	10 7	390

TABLE 296.—WAGON STOCK, MIDLAND RAILWAY.

Wagon.	External Dimensions over Corner Pillars.		Internal Dimensions.			Load to Carry.	Weight of Wagon.	Price.
	Length.	Width.	Length.	Width.	Height above Floor.			
	Ft. Ins.	Ft. Ins.	Ft. Ins.	Ft. Ins.	Ft. Ins.	Tons.	Tns. Cwts.	£
Covered goods	14 11	7 5	14 2	6 10	5 10½	8	5 3	72
High-sided, for goods or coal . .	14 11	7 5	14 6	7 0	2 10	8	5 2	6
Low-sided .	14 11	7 5	14 6	7 0	1 9	8	4 14	61
Cattle wagon	18 6	8 0	17 9	7 4	7 0½	8	6 0	86

Electrical Propulsion on Railways.

In consequence of the number of stages between the generation of steam in the stationary boilers and the hauling of the train, the efficiency of electric propulsion is relatively small. There is, first, the power consumed in driving the engine and dynamo; then, the dynamo cannot give in electrical power all the mechanical power applied to it; then there is the loss by line resistance and leakage; and the loss in the motor. These losses were such, in one case, that the efficiency of the entire plant was only 15·1 per cent. In another case, the efficiency averaged 25 per cent. The cost for power by electric agency is considered to be about four times that of direct steam power.

TRAMWAYS.

The total length of tramway lines in the United Kingdom open for public traffic on the 30th June, 1889, was 949 miles, distributed as follows :—

	Miles open.
England	758
Scotland	81
Ireland	110
	949

Of this length, 407½ miles were double line, and 541½ miles were single line: respectively 42 per cent. and 58 per cent.

The total capital expended at June 30, 1889, amounted to £13,664,591; or £14,400 per mile open.

The working stock was as follows :—

27,060 horses, or . .	28½ horses per mile open.
539 locomotives . .	·57 locomotives ,,
3,645 cars, or . . .	3·84 cars ,,

62,041,013 miles were run by cars.

The gross receipts for the year were £2,980,224; or £3,140 per mile open; or 11½*d.* per car mile run.

The working expenses were £2,266,681, or 76 per cent. of the receipts; or 8¾*d.* per mile run.

Flat foot girder rails of steel, weighing from 80 lbs. to 90 lbs. per yard, are now most commonly laid. They are about 6 inches in height, and from 5 inches to 6 inches wide at the flange-base.

Cars capable of holding 20 passengers inside, and 22 outside, weigh about 2½ tons each. The gross weight, fully loaded, is 5½ tons. The body of the car is 15¼ feet in length, 6 feet 8 inches wide, outside measurement. The total length of the car is 21¼ feet, allowing 3 feet at each end for the platform.

The average resistance to traction is about 30 lbs. per ton of car and its load. When the rails are wet and clean, straight and new, a minimum of 15 lbs. per ton may be reached. An occasional maximum resistance of 60 lbs. per ton may be reached; the augmentation being due mostly to the clogging of the grooves of the rails.

Cost per mile, single line, of sample of Tramway: girder rail 80 lbs. per yard, 7 inches high.

	£	*s.*	*d.*
Steel rails, 80 lbs. per yard, 125¾ tons, @ £8 14*s.*	1,094	0	6
Wrought-iron fish-plates, 4¾ tons, @ £8 . .	38	0	0
,, ,, bolts and nuts, 9 cwt., at 11*s.* .	4	19	0
Lifting and carting away, 522 cubic yards, @ 1*s.* 9*d.*	45	13	6
Excavation, &c., 1,108 cubic yards, @ 2*s.* . .	110	16	0
Portland cement concrete, 6 inches thick, 782 cubic yards, @ 17*s.*	664	14	0
Laying tramway, 1,760 yards, @ 1*s.* 8*d.* . .	146	13	4
Total for the way	2,104	16	4
Paving, &c., 2,836 square yards, @ 7*s.* 3*d.* . .	1,028	1	0
Paving in cement and sand, next rails, 1,564 square yards, @ 7*s.* 7*d.*	593	0	4
Grouting joints of sets with bitumen, 4,400 square yards, @ 1*s.* 3½*d.*	284	3	4
Total for paving	1,905	4	8
Total for way and paving	4,010	1	0

Steam Power on Tramways.

Kitson & Co.'s engines on the Birmingham Central Tramways weigh, with water and coal, from 9 to 10 tons. They draw a car holding 60 passengers. On the same line, the engines of the Falcon Company have 8-inch cylinders, with 14 inches of stroke, and 2½ feet wheels. In drawing two loaded cars weighing together 18½ tons, at a speed of 6 miles per hour, on a gradient of 1 in 25, they indicated 40 horse-power, consuming from 8 to 9 pounds of coke per mile.

Compressed-Air Tramway Engines.

Mekarski's system of employing compressed air, heated by an admixture of steam, is in operation on the Nantes tramways. The efficiency of the air-compressors is 76 per cent. in volume of air delivered: one kilogramme, or 2·205 pounds of air, compressed to a pressure of 426 lbs. per square inch, supplies energy equivalent to 90.375 foot-pounds, and 100 kilogrammes, or 220 pounds of compressed air, is sufficient to propel a car of 8 tons loaded weight for a distance of from 7½ to 8 or 9 miles. The cars have seats for 19 persons, a platform for 15 or 16 at one end, and the heater and the driver's cab at the other end. The total length is 23¼ feet, and the width is 7¼ feet. The weight of the car is 6 tons empty, 8 tons full. of which the adhesion weight is 4½ tons. The compressed air is contained in 10 cylindrical reservoirs. placed transversely underneath the platform, connected by pipes, in two sets, to form a working and a reserve battery, having respectively 70 and 28 cubic feet of capacity; together, 98 cubic feet, and holding, when charged, 220 pounds of compressed-air. The working cylinders are outside, 5¼ inches in diameter, with a stroke of 10¼ inches; the compressed air is cut off at one-third. The driving wheels are 27½ inches in diameter. The heater has a capacity of 28 gallons, and the water is heated to 300° F. by the injection of steam before starting. The consumption of compressed air varies from 23 pounds to 28½ pounds per mile. The working cost is at the rate of about 6*d*. per mile-run.

From the results of trials made by D. K. Clark of one of Hughes & Lancaster's low-pressure compressed-air tramcars, propelled by means of four single-acting 5-inch cylinders, of 3 inches stroke, it appears that the consumption of compressed air was at the rate of 30½ pounds per mile-run for a level. The car, with passengers, weighed 4¼ tons; and the work done was at the rate of 22,070 foot-pounds per pound of air. The maximum working pressure of compressed air was 132 lbs. per square inch.

Electrical Propulsion on Tramways.

The Bessbrook and Newry Tramway, 3 miles long, has an average gradient of 1 in 86, and a maximum gradient of 1 in 50; and is to a 3 feet gauge. It is worked by electric power. Two passenger cars, 33 feet and 21 feet 8 inches long, are each provided with a motor. The longer car weighs 8¼ tons, comprising 2 tons, 1 cwt., 1 quarter, the weight of the dynamo, bed-plate, armature, and accessories. The shorter car is similar to the longer; and there is a third passenger car 33 feet long, weighing 5½ tons. The generator is worked by a fall of water, 28 feet high. There are two generating dynamos for a normal output of 250 volts, 72 ampères, at a speed of 1,000 revolutions per minute, for which the electrical efficiency is 92·2 per cent., and the commercial efficiency 90·4 per cent. The conductor is of channel steel, laid midway between the rails or under insulators. The circuit is completed by the rails of the permanent way, which are uninsulated. Each locomotive car is fitted with an Edison-Hopkinson dynamo-motor. A speed of one mile per hour corresponds to 100 revolutions of the dynamo-axle per minute. Three trains, having six trucks, four trucks, and no trucks respectively, and weighing 28·64 tons, 21·9 tons, and 8·8 tons, including the weight of the locomotive, were tried for efficiency. The leading results are given in Table 297, and the percentages in Table 298.

TABLE 297.—BESSBROOK AND NEWRY TRAMWAYS: RESULTS OF ELECTRICAL TRACTION.

Items.	First Journey.	Second Journey.	Third Journey.
	Tns. Cwts. Qrs.	Tns. Cwts. Qrs.	Tns. Cwts. Qrs.
Gross load	28 12 3	21 18 0	8 16 0
Average speed, in miles per hour	5·7	7·2	11·3
Total energy of water, in foot-pounds	60,291,000	40,860,600	27,522,000
Total electrical energy developed by generator, in foot-pounds	35,871,000	21,516,000	9,332,400
Total mechanical energy developed by motor, in foot-pounds	24,928,200	15,493,500	7,170,900
Sum of electrical losses, in foot-pounds	12,493,800	5,841,000	2,174,700
Loss in generator, in foot-pounds	3,343,000	1,735,800	801,900
,, leakage ,, ,,	1,420,300	1,029,600	775,500
,, resistance of line, in foot pounds . . .	3,613,500	1,296,900	287,100
,, motor, in foot-pounds .	4,098,600	1,791,900	326,700
Total work done against gravity	11,867,400	7,356,800	2,858,800
,, ,, friction	13,060,800	8,136,700	4,312,600
Average tractive forces, exclusive of gravity, in pounds per ton	28·9	27·4	37·1

TABLE 298.—BESSBROOK AND NEWRY TRAMWAYS: PERCENTAGE DISTRIBUTION OF POWER.

Items.	1st Journey.		2nd Journey.		3rd Journey.	
	Water Power.	Total Power of Generator.	Water Power.	Total Power of Generator.	Water Power.	Total Power of Generator.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Water power . .	100·0	...	100·0	...	100·0	...
Generator power .	59·5	100·0	52·6	100·0	33·9	100·0
Net motor power .	41·3	69·4	37·9	72·0	26·1	76·8
Loss in generator .	5·5	9·3	4·2	8·0	2·9	8·6
,, leakage .	2·3	3·9	2·5	4·8	2·8	8·3
,, line resistance .	6·0	10·6	3·2	6·0	1·0	3·1
,, in motor .	6·8	11·4	4·4	8·3	1·2	3·5

The Barking Road section of the North Metropolitan Tramways is worked by electrical power by contract, charged for at the rate of about $4\frac{1}{2}d.$ per car mile run, including the wages of the driver.

Resistance to Traction on Common Roads.

(F. V. Greene.)

WAY.	Pounds per ton.
Iron	10 lbs.
Asphalte	15 ,,
Wood	21 ,,
Best stone blocks	33 ,,
Inferior stone blocks	50 ,,
Average cobble stone	90 ,,
Macadam	100 ,,
Earth	200 ,,

STEAM-SHIPS.

The gross register tonnage of a ship is reckoned at the rate of 100 cubic feet of capacity per ton, by the formula :—

$$\text{Register tonnage} = C\frac{L\,B\,D}{100} \qquad (1)$$

L = inside length on the upper deck from the plank at the stem to the plank at the stern, in feet.
B = inside main breadth from ceiling to ceiling, in feet.
D = inside midship depth from the upper deck to the ceiling at the limber strake, in feet.
C = a constant, the values of which are as follows :—

		C
Sailing ships		·70
Steam vessels and clippers	Ships of 2 decks	·65
	Ships of 3 decks	·68
Yachts	Above 60 tons	·50
	Under 60 tons	·45

The values thus obtained express the entire cubical capacity of the ship. Deductions are allowed for buildings erected for the shelter of passengers only, for crew space at the rate of 72 cubic feet per man, and propelling space. This third item, for screw steamers, is taken as 32 per cent. if the cubic content is 13 per cent. and under 20 per cent. of the gross tonnage; if the space is smaller than 13 per cent. and larger than 20 per cent., deduct 32 per cent., or 1¾ times the content. For paddle-steamers, deduct 37 per cent., if the content is 20 per cent. and under 30 per cent.; if the space is smaller than 20 per cent. or larger than 30 per cent., deduct 37 per cent., or 1½ times the content.

Builder's measurement is computed in terms of the length and the breadth by the formula :—

$$\text{Tonnage} = \frac{(L - {\cdot}60\ B)\ 1{\cdot}5\ B}{94} \quad . \quad . \quad (2)$$

L = length measured from the back of the main stern post to a vertical from the fore part of the main stem under the bowsprit, in feet.

B = the extreme breadth to the outside planking, exclusive of doubling planks, in feet.

Resistance of Ships.

The thrust on the collars of the propeller shaft is a measure of the power actually exerted for the propulsion of the vessel. Let P = the thrust or pressure of the propeller against the thrust bearing in pounds; and S = the speed of the ship in feet per minute; the effective horse-power is,—

$$\frac{S \times P}{33{,}000}$$

Taking it as two-thirds of the indicator power, which is a usual proportion, $\frac{2}{3}$ I. H. P. $= \frac{S \times P}{33{,}000}$; and

$$P = \text{I. H. P} \times \frac{22{,}000}{S} \quad . \quad . \quad . \quad (3)$$

The effective indicator horse-power required to propel a steam-ship is given by the following formulæ :—

$$\text{Eff. I. H. P.} = \frac{D^{\frac{2}{3}} \times S^3}{C} \quad . \quad . \quad (4)$$

$$\text{Eff. I. H. P.} = \frac{A \times S^3}{K} \quad . \quad . \quad . \quad (5)$$

I. H. P. = effective indicator horse-power, or the net indicator power for propulsion.

D = displacement, in tons.

S = speed in knots per hour.

A = immersed mid ship section, in square feet.

C = a constant.

K = a constant.

The results obtained by means of these formulæ are to be taken as only approximate. The first is the more trustworthy. The following are a few values of the constants C and K :—

Length.	Speed.	C.	K.
Less than 200 feet .	About 10 knots	210	600
200 to 250 feet . .	11 „	220	600
250 to 300 „ .	12 „	240	620
300 to 400 „ . .	15 „	250	650
Over 400 „ .	17 „	240	620

The effective indicator horse-power may also be calculated in terms of the area of wetted surface, by the formula :—

$$\text{Eff. I. H. P.} = \frac{W \times S^3}{20{,}000} \quad . \quad . \quad . \quad (6)$$

W = area of wetted surface, in square feet.
S = speed in knots per hour.

Forced Draught in Marine Boilers.

A blast of compressed air was applied in the chimney of the "Résolue," with the results given in Table 299.

TABLE 299.—COMPRESSED-AIR EXHAUSTING BLAST ON THE S.S. "RÉSOLUE."

Horse-power of the Blowing Engine.	Horse-Power of the Main Engine.	Coal Consumed per Hour (Anzin briquettes).	Coal per Indicator Horse-Power per Hour.	Water Evaporated per Pound of Coal.
I. H.-P.	I. H.-P.	Pounds.	Pounds.	Pounds.
0·00 natural draught	57·5	213	3·72	10·77
0·96	88·8	289	3·26	8·82
2·00	100·5	315	3·12	8·00
3·00	106·1	321	3·04	7·82
4·20	118·8	348	2·93	7·82
5·00	119·8	374	3·12	7·53
6·00	127·9	400	3·12	7·00
7·40	135·7	420	3.10	7·03

The fuel consumed and the power were doubled, but the evaporative efficiency was reduced.

From the results of trials on ships of the Navy, it appears that with open stokeholds and natural draught versus closed stokeholds and forced draught, the indicator power of the engines was increased by 52½ per cent.; and 65 per ton of boiler.

By Mr. Fothergill's system of closed ashpits and forced draught, there is an economy of 20 per cent. of coal for steaming.

With a combined forced and induced draught by compressed air into the ashpit, the speed of a steam launch was increased from 3 knots to 6 knots per hour. The quantity of water evaporated per hour was trebled.

By an induced draught caused by an exhausting fan at the base of the chimney of a marine boiler, nearly three times as much water was evaporated as by natural draught; about 6 per cent. less water was evaporated per pound of coal.

Average Weight of Steam-Engines with Boilers, Water, and all Fittings per Indicator Horse-power.

(F. C. Marshall.)

	Per I. H. P.
Merchant steamer	480 lbs.
Royal Navy	360 "
Engines specially designed for light-draught vessels	280 "
Royal Navy, Polyphemus Class . . .	180 "
Locomotive	140 "
Torpedo vessels	60 "
Ordinary Marine boilers, with water . .	196 "
Locomotive boilers, with water . . .	60 "

Average Proportions and Results of Performance of Compound Engines.

(F. C. Marshall.)

		Average.
Speed of piston, in feet per minute .	from 350 to 550 . .	467 ft.
Working pressure of steam above the atmosphere . .	" 70 lbs. to 100 lbs. .	77·4 lbs.
Condensing surface .	" 1,518 to 7,427 sq. ft.	
Heating surface .	" 2,379 to 11,045 "	
" " per I. H. P. . . .	" 2·77 to 6·30 "	3·92 sq. ft.
Indicator horse-power . . .	" 560 to 2,745 I. H. P.	
Coal consumption in 24 hours . . .	" 11 to 51·9 tons.	

		Average.
Coal consumption per I. H. P. per hour . . .	from 1½ to 2 lbs. . .	1·83 lbs.
Heating surface per pound of coal per hour . . .	,, 1·65 to 3·12 sq. ft. .	2·18 sq. ft.

The above proportions apply with sufficient nearness to the multiple compound practice of to-day, excepting that higher pressures are employed, up to 160 lbs. per square inch in the boiler; and that the consumption of coal may, under good conditions, be reduced as low as 1·44 lbs. per I. H. P. per hour.

Horse-power of Marine Engines.

The North East Coast Institution of Engineers and Shipbuilders have framed a general rule for what they designate the Normal Indicator Horse-power on loaded trial trip of surface-condensing marine screw engines working at any boiler pressure between 50 lbs. and 250 lbs. per square inch.

$$\text{(For screw engines) N. I. H. P.} = \frac{(D^2 \sqrt[3]{S} + 3\,H)\,\sqrt[3]{P}}{100} \quad . \quad (7)$$

D = diameter of low-pressure cylinder, in inches.
S = stroke of piston, in inches.
P = working boiler pressure, in lbs. per square inch above the atmosphere.
H = heating surface of boilers, in square feet.
P_m = mean pressure in lbs. per square inch, reduced to low-pressure cylinder.
R = revolutions per minute.
N. I. H. P. = maximum normal indicator horse-power, or loaded trial trip, of surface-condensing marine screw engines.

The conditions assumed as normal are: 1. That the steam, whatever its initial pressure, is expanded in the engines to the same pressure. 2. That the expansion is effected in the engines with the same degree of efficiency for all pressures between 50 lbs. and 250 lbs. per square inch. On this condition, for the higher pressures, engines of triple, quadruple, or more expansions, must be employed, the number of expansions depending on the initial pressure. From conditions 1 and 2, it follows that the mean pressure reduced to the low-pressure cylinder, P_m, may be assumed as proportional to the cube root of the boiler pressure, $\sqrt[3]{P}$; and that its actual loaded trial-trip value may be taken without sensible error as 5·6 $\sqrt[3]{P}$. 3. That the piston speeds of engines of different lengths of stroke, are proportional to the cube roots of their respective strokes; and that the actual loaded trial-trip value of piston speed may be taken as 144 $\sqrt[3]{S}$. 4. That in all cases where the engines and boilers bear to each other such proportions as to prevent condition 1 from being fulfilled, without thereby violating condition 3, the coal consumption per indicator horse-power will not be affected, but will be constant for the same boiler pressure. 5. That the boilers are constructed in accordance with the fair average practice of the present day; that if forced draught be employed, it does not exceed the average chimney draught; that the horse-power is proportional to the heating surface, H., and to the cube root of the pressure, $\sqrt[3]{P}$; and that the actual loaded trial-trip horse-power may be taken as $\frac{H \sqrt[3]{P}}{16}$. 6. That the efficiency of the engine mechanism is constant, and that the propeller is such that the engines may utilise the boiler power in the manner prescribed in conditions 3 and 4.

Deductions from the Rule.

$$\text{I. H. P. of engines} = D^2 \sqrt[3]{P\,S} \quad . \quad . \quad . \qquad (8)$$

$$\text{I. H. P. of boilers} = \frac{H \sqrt[3]{P}}{16} \quad . \quad . \quad . \quad . \qquad (9)$$

These values (8) and (9) are equal; and, reducing,—

$$\text{(For screw engines) } H = \frac{D^2 \sqrt[3]{S}}{3{\cdot}25} \quad . \quad . \qquad (10)$$

Assuming that half the sum of the powers calculated for the engines and boilers taken together, or the mean of the powers, represents the effective power of the system,—

N. I. H. P. of screw engines and boilers jointly =

$$\frac{(D^2 \sqrt[3]{S} + 3\,H) \sqrt[3]{P}}{100} \quad . \quad . \quad . \qquad (11)$$

For paddle engines, the same formula is available, with a suitable co-efficient. Taking the piston speed at 90 $\sqrt[3]{S}$:—

$$\text{(For paddle engines) N. I. H. P.} = \frac{(D^2 \sqrt[3]{S}. + 5\,H) \sqrt[3]{P}}{160} \qquad (12)$$

$$H = \frac{D^2 \sqrt[3]{S}}{5{\cdot}2} \quad . \quad . \quad . \quad . \qquad (13)$$

What is known as nominal horse-power may be valued at one-sixth of the normal indicator horse-power.

In America, a standard of horse-power has come into practice, measured by 30 pounds of water evaporated per hour. at a pressure of 70 lbs. per square inch above the atmosphere. from 100° F. per horse-power.

PUMPING STEAM-ENGINES AND PUMPS.

The net work done, or duty effected by a pump, is equal to the product of the weight in pounds of water lifted by the height in feet through which it is raised. The efficiency of the pump is the ratio of the effective work done to the whole work expended in driving the pump. The efficiency increases generally with the height of the lift, as shown in Table 300.

TABLE 300.—EFFICIENCY, OR RATIO OF DUTY TO ENGINE-POWER, OF LARGE PUMPING ENGINES.

	Head, in Feet.	Efficiency per Cent.
Cornish pumping engines . .	140	90·8
Rotative beam engine	20·5	86
Rotative Woolf beam . .	210	85 to 88
Rotative receiver beam . .	35	77·4
Rotative compound beam . .	169	83·7
Worthington pump	60·6	85
" "	148·5	91·5

The duty of a pumping engine is defined as the number of pounds of water lifted one foot high, by the consumption of 1 cwt. of coal (112 pounds). The duty may be deduced from the performance of a pumping engine expressed in pounds of coal consumed per indicator horse-power, by dividing 1,980,000 by the given pounds of coal, and multiplying the quotient by 112.

Conversely, the fuel consumed per net horse-power of the pump may be calculated from the duty expressed in foot-pounds per cwt. of coal, by dividing the duty by 112, to give the duty per pound of fuel ; and dividing the quotient into

1,980,000. The final quotient is the quantity of coal in pounds consumed per horse-power per hour.

Or, divide 222 by the duty in millions of pounds lifted one foot per cwt. of fuel. The quotient is the quantity of coal consumed in pounds per horse-power per hour.

The duty or effective horse-power of pumping engines, varies from 75 per cent. to 85 per cent. of the indicator power, for vertical direct-acting and beam-rotative engines. For horizontal pumping engines, the duty horse-power is about 85 per cent. of the indicator power. The Worthington horizontal compound direct-action pumping engine, tested by Mr. J. G. Mair, realised a duty power 91½ per cent. of the indicator power; or, deducting 3½ per cent. for the aid of an auxiliary engine to work the air-pump and the feed-pump, a net efficiency of 88 per cent. is obtained.

The slip of large reciprocating pumps varies from 5 per cent. to 1½ per cent., or occasionally less: showing that from 95 per cent. to 98½ per cent. of the working capacity of the pump is utilised. An average of 2½ per cent. of slip may be taken. It is customary to include an allowance of 5 per cent. for slip. In rare instances there is no slip.

Of the four values, the area and stroke of the pump, and the area and stroke of the steam cylinder, or of the second cylinder of a compound engine, to find the value of one, when those of the three others are known. The product of the area of the steam cylinder by the effective average pressure per square inch is equal to the product of the area of the pump barrel by the load in pounds per square inch, plus an allowance, say, of 25 per cent. to overcome frictional resistance. Whence the following rules, in which the areas of the cylinder and the pump-barrel are expressed in square inches, and the pressures and loads in pounds per square inch:—

1. *To find the required area of the cylinder.* Multiply the area of the air-pump by the load on the pump, and divide by the effective average pressure of steam available in the cylinder. Add 25 per cent. of the area for friction.

2. *To find the average effective steam pressure required in the cylinder.* Multiply the area of the pump by the load on the pump, and divide by the area of the cylinder. The quotient is the effective average pressure required to balance the load. Add 25 per cent. of the pressure for friction.

3. *To find the load against which the pump will deliver water.* Multiply the area of the cylinder by the effective average steam pressure, and divide by the area of the pump. From the quotient deduct 20 per cent. for friction; the remainder is the pressure or load under which water will be delivered.

4. *To find the area of the pump-barrel.* Multiply the area of the cylinder by the effective average steam pressure, and divide by the load. Deduct 20 per cent. for friction; the remainder is the area of pump-barrel required to balance the load.

In the case of compound engines, the area of the second cylinder is to be taken into the calculation; and the effective average pressure in the first cylinder is to be reduced in the ratio of the area of the second cylinder to that of the first cylinder; and, thus reduced, added to the effective average pressure in the second cylinder. The sum is to be adopted for calculation as in the case of a single cylinder.

Speed of Pistons.

The speed of steam-pistons may be from 100 feet to 200 feet per minute. The water may pass through the service-pipes at speeds of from 150 feet to 350 feet.

Six-inch three-throw pumps, raising water, performed the following duties for corresponding lifts, in parts of the indicator power:—

Water per Hour.	Lift.	Efficiency.
120 barrels	165 feet	77 per cent.
160 „	140 „	65·6 „
80 „	54 „	78·5 „
250 „	48 „	45·0 „

Centrifugal Pumps.

TABLE 301.—RAISING WATER FROM DEEP WELLS.

(Appleby.)

Quantity of Water lifted per Hour.	Lift for One Man on Crank.	Lift for One Donkey Engine.	Lift for One Horse Engine.	Lift for One Horse-Power Steam-Engine.
Gallons.	Feet.	Feet.	Feet.	Feet.
200	90	180	630	990
350	52	102	357	561
500	36	72	252	396
650	28	56	196	308
800	22	45	154	242
1000	18	36	126	198

The maximum duty of a centrifugal pump worked by a steam-engine, according to the late Mr. David Thomson, varies from 55 per cent. for smaller pumps to 70 per cent. for larger pumps. For lifts of from 15 to 20 feet, they are as economical of power as ordinary pumps; for lifts of 4 or 5 feet they are more efficient.

The height to which water would ascend in a pipe by the action of centrifugal force, would, if there were no other resistances, be that due to the velocity of the circumference of the revolving wheel, or to $\frac{v^2}{2g}$ or $\frac{v^2}{64}$.

Chain Pumps.

An endless chain, fitted with floats, circulating continuously, and drawing up an inclined plane, utilises in duty, 40 per cent. of the power applied. Lifting water through a vertical pipe, the efficiency is 65 per cent. The slip is about 17 per cent.

Hydraulic Rams.

The efficiency of the hydraulic ram is expressed by Daubuisson's formula:—

$$\frac{d'h'}{dh} = 1{\cdot}42 - {\cdot}28\sqrt{\frac{h'}{h}} \quad . \quad . \quad . \quad (1)$$

d = quantity of water used, in gallons per minute.
d' = quantity of water raised, in gallons per minute.
h = head used, in feet.
h' = lift, in feet.

TABLE 302.—EFFICIENCY OF HYDRAULIC RAMS.

Ratio of Lift to Fall. Fall = 1.	Efficiency.	Ratio of Lift to Fall. Fall = 1.	Efficiency.	Ratio of Lift to Fall. Fall = 1.	Efficiency.	Ratio of Lift to Fall. Fall = 1.	Efficiency.
Ratio.	Per cent.	Ratio.	Per cent.	Ratio.	Per cent.	Ratio.	Per cent.
4	72	10	44	16	25	22	9
5	66	11	41	17	22	23	7
6	61	12	37	18	19	24	4
7	57	13	34	19	17	25	2
8	52	14	31	20	14	26	0
9	48	15	28	21	12		

The Table 302 of efficiencies was calculated by means of this formula, only five-sixths of the calculated values being taken, in order to cover contingencies.

According to Eytelwein's formula, the proper diameter of the driving-pipe, in inches, is equal to the square root of the quantity of water in gallons per minute.

Cast-Iron Water-Pipes.

The suitable thickness of cast-iron water-pipes is given by the formulæ,—

$$t = \cdot 25 + \frac{\mathrm{H}d}{9600} \quad . \quad . \quad . \quad . \quad . \quad . \qquad (2)$$

$$t = \cdot 25 + \frac{pd}{4250} \quad . \quad . \quad . \quad . \quad . \quad . \qquad (3)$$

t = thickness of pipe, in inches.
H = head of pressure, in feet of water.
d = inside diameter of pipe, in inches.
p = the interior pressure, in pounds per square inch.

For the usual head, 300 feet of water, the formula (2) becomes,—

$$t = \cdot 25 + \cdot 031\, d \quad . \quad . \quad . \quad . \quad . \quad . \qquad (4)$$

For socket ends, the equivalent length of pipe, equal in weight to that of the socket, is given by the formula,—

$$\text{Equivalent length in inches} = 7 + \frac{d}{15} \quad . \quad . \quad . \qquad (5)$$

$$\text{,, \quad ,, \quad feet} = \cdot 6 + \frac{d}{180} \quad . \quad . \quad . \qquad (6)$$

The additional weight for a pair of joint-flanges is equivalent to that of a lineal foot of pipe.

COAL GAS, &c.

TABLE 303.—PRODUCTS OF DISTILLATION OF COAL, PER TON.

	Wigan Cannel.	Wigan Coal.	Newcastle Coal.
Gas	10,900 cub. ft.	9980 cub. ft.	9700 cub. ft.
Coke	1436 pounds.	1517 pounds	1540 pounds
Tar	17 gallons	11 gallons	9 gallons
Ammoniacal liquor .	18 ,,	20 ,,	10 ,,
Illuminating power of gas . . .	24 sperm candles	15 candles	15 candles
Percentage of coke .	64 per cent.	68 per cent.	70 per cent.

Average Yield of Bituminous Coal, by Weight.

(Newbigging.)

	Per cent.
Gas	18
Coke and breeze	68
Tar	5
Ammoniacal liquor	9
	100

TABLE 304.—RESULTS OF DISTILLATION OF ONE TON OF NEWCASTLE CANNEL COAL, FOR GAS AND FOR OIL.

(Gesner.)

Distilled for Gas, at from 1000° to 1200° F.		Distilled for Oil, at from 750° to 800° F.	
Gas	7450 cub. ft.	Gas	1400 cub. ft.
Tar	18½ gallons	Crude oil	68 gallons
Coke	1200 pounds	Coke	1280 pounds
Products of the Tar.		*Products of the Crude Oil.*	
Benzole	3 pints	Eupion	2 gallons
Coal-tar naphtha	3 gallons	Lamp Oil	22½ "
Heavy oil and naphthaline	9 "	Heavy oil and paraffin	24 "
	12⅜ "		48½ "

TABLE 305.—AVERAGE COMPOSITION OF LONDON GAS, BY VOLUME.

(Dr. Letheby, 1866.)

Description of Gas.	Common Gas.	Cannel Gas.
	Per cent.	Per cent.
Hydrogen	46·0	27·7
Light carburetted hydrogen	39·5	50·0
Olefiant gas	3·8	13·0
Carbonic oxide	7·5	6·8
Carbonic acid	0·7	0·1
Aqueous vapour	2·0	2·0
Nitrogen	0·5	0·4
	100·0	100·0

TABLE 306.—LONDON COAL GAS:—COMPOSITION AND CALORIFIC VALUE.

(Society of Arts. 1889.)

Constituents.	Proportion by Volume.	Weight of One Cubic Foot of the Gas named in Column 1.	Weight in One Cubic Foot of Coal Gas.	Proportion by Weight.	Calorific Value per Pound of the Gas down to 100° C.	Calorific Value per Pound of Coal Gas down to 100° C.	Proportional Weight of Oxygen Required for Complete Combustion of One Pound of the Gas.	Weight of Oxygen Required for Complete Combustion of One Pound of Coal Gas.	Weight of Products of Combustion for One Pound of Coal Gas.	
		At Standard Pressure and Temperature.							Steam.	Carbonic Acid.
	Per Cent.	Lbs.	Lbs.	Per Cent.	Thermal Units.	Thermal Units.	Lbs.	Lbs.	Lbs.	Lbs.
CH_4 . .	37·34	·447	·01669	52·8	21510	11357	4	2·112	1·188	1·452
C_2H_4, &c. .	3·77	·1410	·00532	16·9	20100	3397	$2\frac{4}{7}$	·579	·217	·531
H . . .	50·44	·00559	·00282	8·9	52200	4646	8	·712	·801	...
CO . .	3·96	·0783	·00310	9·8	4350	426	$\frac{4}{7}$	·056	...	·154
N . . .	3·98	·0783	·00312	9·9	...	...	...	...	...	...
CO_2 and O	·51	·1060	·00054	1·7	...	...	...	...	...	...
	100·00	...	·03159	100·0	...	19826	...	3·459	2·206	2·137

Calorific value of one cubic foot = 19826 × ·0316 = 626 thermal units.

" one pound = 19800 thermal units.

Weight of Coal.

	Per Cubic Foot, Solid.	Per Cubic Foot, Heaped.	Cubic Feet in One Ton, Heaped.
Anthracite	85·4 lbs.	58·3 lbs.	38·4 cubic feet.
Bituminous	78·3 „	49 8 „	45·3 „
Cannel	76·8 „	48·3 „	46·4 „

TABLE 307.—CALORIFIC VALUE OF COAL GAS.

(T. L. Miller.)

Place of Manufacture.	Heating Power per Cubic Foot.
	Heat-Units.
Glasgow	813
Liverpool	770
Kilmarnock	680
Manchester	654
Birmingham	639
London	624
Hoboken	617
Berlin	549

Weight of Lime.

1 bushel of quicklime weighs about				70 lbs.
1 cubic foot	„	„	„	54 „
1 cubic yard	„	„	„	1460 „
1 ton	„	measures about 32 bushels.		

Area of pipe-surface required for condensation of gas—10 square feet per 1000 cubic feet of maximum production per day of 24 hours (*Newbigging*).

Illuminating Power of Gas.

The standard for comparison of gases for illuminating power is the sperm candle, weighing six to the pound, each burning off at the rate of 120 grains of sperm per hour. The gas for comparison is burned at the rate of 5 cubic feet per hour.

The gas supplied in London averages more than 16 candles for illuminating power. In fact, the larger companies are required, by Acts of Parliament, to supply gas of such a quality, that when burned through the Government standard Argand burner at the rate of 5 cubic feet per hour, it shall be capable of giving a light equal to that of 16 spermaceti candles, of six to the pound, when each candle is burning at he rate of 120 grains of material per hour. This is called ommon gas. The London companies, and most provincial ompanies, are required to maintain in all their street mains a ressure equal to a column of water 1 inch in height, between unset and midnight; and a pressure of $\frac{9}{10}$ inch between midight and sunset.

Main Pipes.

Main pipes should be tested to 150 feet of water pressure.

Cast-iron pipes below 3 inches bore, are made in lengths of feet; from 3 inches to 11 inches, 9 feet long; 12 inches nd upwards, 6 feet or 9 feet long.

The weight of cast-iron pipes is given by the formula, —

$$W = 2 \cdot 45\ (D^2 - d^2) \quad . \quad . \quad . \quad (1)$$

D = diameter, outside, in inches.
d = diameter inside, in inches.
W = weight in pounds per lineal foot.

The weight of a socket is equal to $\frac{8}{10}$ths of that of a lineal oot of the pipe.

TABLE 308.—THICKNESS OF CAST-IRON GAS MAIN PIPES.

Diameters.	Thickness.	Diameters.	Thickness.	Diameters.	Thickness.
Inches.	Inches.	Inches.	Inches.	Inches.	Inches.
1, $1\frac{1}{2}$, 2	$\frac{5}{16}$	12, 13, 14, 15	$\frac{5}{8}$	30	1
$2\frac{1}{2}$, 3, 4	$\frac{3}{8}$	16, 17, 18	$\frac{11}{16}$	36	$1\frac{1}{8}$
5, 6	$\frac{7}{16}$	19, 20, 21	$\frac{3}{4}$	42	$1\frac{3}{16}$
7, 8, 9	$\frac{1}{2}$	22, 23	$\frac{13}{16}$	48	$1\frac{1}{4}$
10, 11	$\frac{9}{16}$	24	$\frac{7}{8}$		

TABLE 309.—THICKNESS AND WEIGHT OF WROUGHT-IRON GAS PIPES.

Diameter.	Thickness.	Weight per Lineal Foot.
Inches.	Inch.	Pounds.
3, $3\frac{1}{2}$	$\frac{5}{32}$ full	6, 7
4, 5, 6	$\frac{3}{16}$	9, $10\frac{1}{2}$, 13
7, 8, 9	$\frac{1}{4}$ bare	16, 20, $24\frac{1}{2}$
10, 12	$\frac{1}{4}$	28, 33
14, 16	$\frac{5}{16}$	43, 50

TABLE 310.—SMALL GAS-TUBES.

Diameter Inside.	Light.		Heavy.	
	Weight per Yard.	Length of Bundles.	Weight per Yard.	Length of Bundles.
Inches.	Lbs. Oz.	Yards.	Lbs. Oz.	Yards.
$\frac{1}{4}$	0 $11\frac{1}{2}$	80	0 15	67
$\frac{3}{8}$	1 2	60	1 $6\frac{1}{2}$	46
$\frac{1}{2}$	2 0	32	2 10	16
$\frac{5}{8}$	2 4	25	3 0	20
$\frac{3}{4}$	3 3	23	3 12	19
1	4 8	26	6 0	20
$1\frac{1}{4}$	8 0	16	10 0	12
$1\frac{1}{2}$	12 0	10	14 0	9
2	18 1	5	21 0	5

TABLE 311.—SMALL BRASS TUBES.

Diameter Outside.	Weight per Foot.	Diameter Outside.	Weight per Foot.
Inches.	Pounds or Ounces.	Inches.	Pounds or Ounces.
$\frac{1}{4}$	·08 or 1·28	$\frac{7}{8}$	·50 or 8·00
$\frac{5}{16}$	·15 „ 2·40	1	·59 „ 9·44
$\frac{3}{8}$	·19 „ 3·04	$1\frac{1}{4}$	·81 „ 12·96
$\frac{7}{16}$	·21 „ 3·36	$1\frac{1}{2}$	1·00 „ 16·00
$\frac{1}{2}$	·25 „ 4·00	$1\frac{3}{4}$	1·12 „ 17·92
$\frac{9}{16}$	·31 „ 4·96	2	1·25 „ 20·00
$\frac{5}{8}$	·37 „ 5·92	$2\frac{1}{2}$	1·50 „ 24·00
$\frac{3}{4}$	·43 „ 6·88	3	1·87 „ 29·92

Flow of Gas through Pipes.

Dr. Pole's formula for the volume of gas delivered through large pipes is as follows,—

$$Q = 1350\, d^2 \sqrt{\frac{hd}{sl}} \qquad \ldots \qquad (2)$$

Conversely, the diameter of pipes required for a given rate of delivery, is,—

$$d = \sqrt[5]{\frac{Qsl}{(1350)^2 h}} \qquad \ldots \qquad (3)$$

Q = quantity of gas delivered, in cubic feet per hour.
l = length of pipe, in yards.
d = diameter of pipe, in inches.
h = pressure in inches of water.
s = specific gravity of gas = ·40 ; that of air being = 1.

For any other specific gravity, multiply the value of Q given by formula (2), by ·6325 (or $\sqrt{0\cdot40}$), and divide the product by $\sqrt{\text{specific gravity}}$.

The discharge for small pipes is less than the calculated quantity. The value of *d* by formula (3) is to be augmented one-third for lead service pipes; and one-half for wrought-iron service pipes.

Dowson Gas.

The Dowson gas is a cheap gas, generated by passing a mixture of superheated steam and air through a mass of red-hot carbonaceous fuel—anthracite by preference. The composition of the gas, generated with Garnant anthracite, as analysed by Professor William Foster, is as follows,—

	Volume per cent.
Hydrogen	18·73
Marsh gas	·31
Olefiant gas	·31
Carbonic oxide	25·07
Carbonic acid	6·57
Oxygen	·03
Nitrogen	48·98
	100·00

The calorific power of Dowson gas is about one-fourth of that of London gas. The anthracite fuel consumed per 1000 cubic feet is 13·2 pounds. Tested by D. K. Clark, in working an Otto gas engine developing 4·41 indicator horse-power, and 3·26 break horse-power, at a speed of 156 revolutions per minute, the following results were yielded :—

Gas consumed	per	indicator	horse-power	110·34	cubic feet.
„	„	break	„	149·30	„
Fuel	„	indicator	„	1·45	lbs.
„	„	break	„	1·97	„

The cost of Dowson gas is 50 per cent. less than that of coal-gas at 3*s*. per 1000 cubic feet. Whilst coal-gas of average composition requires chemically 5·3 volumes of air for combustion, each volume of Dowson gas requires only 1·1 volume of air.

More recently, Mr. Dowson has produced his gas from ordinary gas-coke. From the results of thirteen Otto engines, using Dowson gas, indicating from 150 to 16 horse-power, it appears that from 1·5 pounds to 1·2 pounds of fuel was consumed per indicator horse-power per hour.

TABLE 312.—OIL GAS, FROM BLUE PARAFFIN OIL.
(Macadam.)

Items.	Pintsch's Apparatus.			Keith's Apparatus.		
	1	2	Mean	1	2	Mean
Specific gravity of oil	·878	·878	·878	·874	·878	·876
Flashing point	296°	294°	295°	292°	286°	289°
Firing point	356°	352°	354°	348°	346°	347°
Gas per gallon, cubic feet	90·7	103·4	97	85	84·8	84·9
Illuminating power	62·5	59·1	60·8	63·2	59·5	61·4
Volume of oil in gallons, flowing in to each retort, per hour	1·4	1·18	1·29	2·3	1·3	1·8
Gas per retort, per hour, cubic feet	126·8	122·5	124·6	197·5	111·9	154·7
Heavy hydrocarbons, per cent.	39·2	37·1	38·2	39·9	38·2	39·0
Gas per ton, cubic feet	23,138	26,356	24,742	21,772	21,671	21,721

TABLE 313.—PRODUCER GAS: COMPOSITION, BY WEIGHT.

Elementary Gases.	H. Hydrogen.	CO. Carbonic Oxide.	CO_2. Carbonic Acid.	CH_4. Marsh Gas.	C_2H_4. Olefiant Gas.	N.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Siemens Producer	·00	24·92	6·95	·89	2·73	64·50
,, ,,	·65	25·97	8·71	1·45	...	63·22
Wilson Producer	·90	29·58	6·91	·91	...	61·70
,, ,,	1·11	26·33	8·29	1·43	...	62·84

Gas Engines.

The Crossley gas engine, horizontal, is constructed with a single cylinder, of nominal powers of from ½ H.P. to 30 H.P., indicating from 2 H.P. to 85 H.P.; and with double cylinders of from 4 H.P. nominal to 30 H.P., indicating from 16 H.P. to 170 H.P. The over-all dimensions of the engine only, single cylinder, vary from 6 feet by 3 feet 7 inches, to 12 feet by 8 feet 2 inches. The speed of the engines is at the rate of 160 revolutions per minute, except for the ½ H.P. and the 1 H.P. engines, which make 180 per minute.

The 12 H.P. engine has developed 28 indicator H.P., and 23 H.P. at the break, or 82 per cent. of the indicator power; consuming 20 cubic feet of gas per indicator horse-power per hour, or 24·3 cubic feet per break horse-power. In a 4 H.P. engine, 23·3 cubic feet was consumed per break horse-power.

The following Table 314, gives some results of trials of a Crossley gas engine.* The cylinder was 9½ inches in diameter, with a stroke of 18 inches; single-acting. The gas used was of the composition shown in Table 306.

TABLE 314.—CROSSLEY GAS ENGINE: RESULTS OF TRIALS.

Trial.	A	B	C
Power	Full	Half	Empty
Revolutions per minute	160·1	158·8	161·0
Explosions per minute	78·4	41·1	10·2
Mean initial pressure . . Lbs.	196·9	196·2	148·0
Mean effective pressure . . „	67·9	73·4	66·7
Indicator horse-power . . H.-P.	17·12	9·73	2·19
Break horse-power . . . „	14·74	7·41	...
Mechanical efficiency . Per cent.	86·1	76·2	...
Gas per hour, main . . Cub. ft.	351·8	202·6	49·0
„ „ for ignition . „	3·5	3·2	...
„ „ total . . „	355·3	205·8	...
Gas per indicator H.P. per hour, main, Cub. ft.	20·55	20·8	22·38
„ „ „ total „	20·76	21·2	...
Gas per break H.P. per hour, main „ .	23·87	27·34	...
„ „ „ total „ .	24·10	27·77	...
Water for cooling per hour . . Lbs.	713	480	...
Rise of temperature . . Fahr.	128°·0	102°·3	...
Power to drive engine only . H.P.	2·38	2·31	2·19
Mean pressure during working stroke, equivalent to work done in pumping strokes . . . . Lbs.	2·19	...	...
Corresponding indicator . H.P.	·55	...	...

The distribution of the heat of combustion of the gas in working the Crossley engine, was as follows,—

Trial.	A. Per cent.	B. Per cent.	C. Per cent.
Heat turned into work	22·1	20·9	19·4
Heat rejected in jacket water	43·2	41·1	...
Heat rejected in exhaust	35·5	38·0	...
	100·8	100·0	...

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* See *Report of the Judges on Trials of Motors for Electric Lighting*, 1889, for the Society of Arts.

TABLE 315.—RESULTS OF TRIALS OF GAS ENGINES. (T. L. Miller.)

Type of Engine.	Tested by	Indicator Horse-Power.	Break Horse-Power.	Gas per I. H. P.	Gas per B. H. P.	Heat Converted into Work.	Revolutions per Minute.	Speed of Piston per Minute.
		I. H. P.	B. H. P.	Cub. Feet.	Cub. Feet.	Per cent.	Turns.	Feet.
Otto	Adams	3·42	2·87	30·9	33·4	14·46	160·3	320·6
,,	,,	22·56	18·31	23·6	29·1	17·5	158·7	423·2
,,	,,	33·6	27·75	25·04	30·3	16·15	151·37	529·7
,,	Society of Arts	17·12	14·75	20·55	23·87	21·2	160·1	480·3
Clerk	Garrett	3·62	2·70	29·8	40	10·5	212	308
,,	,,	9·05	7·23	24·3	30·42	12·9	146	292
,,	,,	27·46	23·21	20·39	24·12	15·5	132	440
Beck	Kennedy	7·35	5·71	21·18	27·27	20·7	212	530
,,	,,	6·12	4·84	20·67	26·14	21·1	168·9	422·8
Griffin	Jamieson	17·28	13·6	19·27	24·48	20·8	183	427
,,	Kennedy	17·46	14·94	18·92	23·58	21·2	223·8	522
,,	Society of Arts	15·47	12·51	22·64	28	19·2	198·1	420·5
Simplex	Witz	...	6·70	...	21·55	19·4	160	420
,,	,,	...	8·67	...	20·12	20·9	160	420
Forward	R. H. Smith	5·54	4·807	20·79	23·97	19·2	...	...
Ajax	Jamieson	10·04	8·84	18·9	21·5	...	...	...
Fawcett	Miller	11·49	8·52	18·4	24·74	19·6	...	...
Atkinson	Unwin	5·536	4·889	19·78	22·51	21·9	...	...
,,	Society of Arts	11·15	9·48	19·22	22·61	22·8	...	...
Hargreaves	Bird	40	tar or creosote	tar or creosote	...	31·4	...	...
,,	,,	5·17	,,	,,	...	14·4	...	...

A Griffin gas engine, double-acting, was similarly tested. The cylinder was 9·02 inches in diameter, with a stroke of 14 inches. Three trials were made at full power, half power and empty.

Trial.	A. Per cent.	B. Per cent.	C. Per cent.
Heat turned into work . . .	21·1	19·4	17·5
Heat rejected in jacket water . .	35·2	32·5	...
Heat rejected in exhaust . .	39·8	48·1	...
Unaccounted for, including heat rejected in blank charge of air .	3·9		

Oil Engines.

Oil engines are in considerable employment as oil motors. In the Priestman oil engine, mineral oil or petroleum is used, having a specific gravity of ·800 or upwards, with a flashing point from 75° to 150°. The oil is mixed with air under pressure, is drawn into the cylinder, and ignited by an electric spark from a small ordinary battery. The consumption of oil varies from about 1·25 pints or 1¼ pounds per break horse-power per hour for the larger engines, to 1·60 pints or 1·60 pounds for the smaller engines. An engine having an 8½-inch cylinder, with a 12-inch stroke, made 180 revolutions per minute, and developed 4·60 break horse-power, with a consumption of 1·20 pints or 1·20 pounds of oil per horse-power per hour. In a half-power trial, 2·36 break horse-power was developed on a consumption of 1·20 pints or 1·20 pounds of oil.

The Hargreaves motor is designed for burning coal-tar or creosote as fuel. It consists of an air-compressing pump and motor cylinder, to the latter of which a regenerator is adapted, which absorbs a portion of the heat of the exhaust gases, and yields it up to the incoming charge. The compressed-air is delivered through the regenerator into the motor cylinder, where it meets a jet of coal-tar or creosote, and, being heated to redness, ignites the fuel. Results of trials are given in Table 315 (p. 567), by Mr. Miller, who gives results of other trials, in one of which, a net power of 40 indicator H.P. was generated, by the consumption of ·512 pounds of coal-tar per indicator horse-power per hour. In another trial, with a smaller engine, for a net indicator power of 5·17 H.P., 1·2 pounds of creosote were consumed per indicator horse-power per hour.

AIR IN MOTION.

DR. HUTTON'S statement of the law of resistance of air to bodies in motion, has been corroborated. It is that in the case of slow motion, the resistance is nearly as the square of the velocity; gradually increasing more and more above that proportion as the velocity increases.

TABLE 316.—RESISTANCE OF AIR TO FLAT VANES, SQUARE AND ROUND.

(Fairweather.)

Size.	Area.	Speed in Feet per Second.					
		5	10	15	20	25	30
Inches.	Sq. Ft.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
SQUARE.							
7·41	·38	·55	1·4	3·25	5·7	9·4	14·0
12·9	1·155	1·30	5·5	13·60	...	...	...
15·58	2·40	3·25	15·0	...	...	...	...
CIRCLE.							
7·24	·286	·30	1·15	2·6	4·6	7·4	10·9
12·65	·875	·85	3·85	9·1	16·4	...	...
18·36	1·840	2·40	10·00	...	...	...	...

Empirical formula for the velocity and pressure of high winds :—

$$P = \frac{V^2}{10} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

$$V = \sqrt{10P} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

V = maximum run of wind in any one hour.

P = maximum pressure, in pounds per square foot, at any time during the storm, to which V refers.

The formula (1) represents very fairly the greatest pressure as deduced from the mean velocity for an hour. The following are the greatest recorded pressures of wind per square foot, at various places :—

	Per Square Foot.	
Aberdeen	41	Lbs.
Armagh	27	,,
Birmingham	27	,,
Edinburgh	35	,,
Falmouth	53·7	,,
Glasgow	47	,,
Greenwich	42	,,
Halifax	30·2	,,
Holyhead	64	,,
Kew	27	,,
Liverpool	90	Lbs.
London	20·2	,,
Valentia	65·6	,,
Yarmouth	42·2	,,
Brussels	22	,,
Paris	17	,,
Bombay	38	,,
Calcutta	40	,,
Madras	34	,,

The Committee appointed to investigate the question, recommended that a maximum wind-pressure of **56 lbs.** per square foot, should be employed in calculations for railway bridges and viaducts.

Flow of Air in pipes.

Mr. Hawksley's formulæ for the flow of air through pipes, under small differences of pressure, are as follows :—

$$v = 396\sqrt{\frac{h\,d}{l}} \qquad . \quad . \quad . \qquad (3)$$

$$h = \frac{l\,v^2}{156{,}800\,a} \qquad . \quad . \quad . \quad . \qquad (4)$$

v = velocity in feet per second.

h = head, or drag, in inches of water.

d = diameter of pipe, in feet.

l = length of pipe, or other passage, in feet.

c = perimeter, in feet.

a = sectional area of pipe, or other passage, in square feet.

Q = Quantity of air discharged, in cubic feet per second.

H = effective horse-power required for net work of discharge of air.

Flow of air through passages of any form of section, as shafts, air-ways, and tunnels.

$$v = 796\sqrt{\frac{a\,h}{c\,l}} \qquad . \quad . \quad . \quad . \qquad (5)$$

$$h = \frac{v^2\,c\,l}{633{,}000\,a} \qquad . \quad . \quad . \quad . \qquad (6)$$

Quantity of Air delivered per Second.

$$\text{From a pipe, } Q = 311\sqrt{\frac{h\,d^5}{l}} \quad . \qquad (7)$$

$$\text{From a passage of any section, } Q = 796\sqrt{\frac{a^3\,h}{c\,l}} \quad . \qquad (8)$$

The density of dry air at 62° F., is taken at $\frac{1}{815}$ part of the density of water at 62·4 pounds per cubic foot; and 1 inch of water as equivalent to a pressure of 5·20 lbs. per square foot.

Effective Horse-power for net work of discharge of air.

$$\text{From a pipe, } H = \frac{v\,d^2\,h}{135} \quad . \quad . \quad . \qquad (9)$$

$$\text{,, } \qquad H = \frac{v^3\,d^2\,l}{21{,}200{,}000} \quad . \quad . \qquad (10)$$

$$\text{from a passage of any section, } H = \frac{v\,a\,h}{106} = \frac{Q\,h}{106} \quad . \qquad (11)$$

$$\text{,, } \quad \text{,, } \quad \text{,, } \qquad H = \frac{v^3\,c\,l}{67{,}000{,}000} \quad . \qquad (12)$$

Natural Flow of Air in Shafts of Mines.

Mr. Hawksley's formula for the velocity of air in the up-cast shaft of a mine, due to difference of temperature is :—

$$v = 96\sqrt{\frac{\dfrac{(T-t)}{(T+448)}\,D\,s}{m\,l + 368\,s}} \quad . \quad . \qquad (13)$$

T = temperature of air in up-cast shaft (Fahr.).
t = temperature of air in down-cast shaft.
D = depth of shaft, in feet.
m = periphery of air course, in feet.
s = section of air-course, in square feet.
l = length traversed by the current, in feet.
v = velocity of current, in feet per second.

Fans.—Ventilators.

The following Table 317, of the most suitable dimensions of fans, is based on the results of Mr. Buckle's experiments. The case is of the form of an arithmetical spiral, widening the clear space between the case and the revolving blades, circumferentially, from the origin to the opening for discharge.

TABLE 317.—DIMENSIONS OF FANS.

Pressure from 3 ounces to 6 ounces per square inch ; or 5·2 inches to 10·4 inches of water.

Diameter of Fan.	Vanes.		Diameter of Inlet Openings.	Diameter of Fan.	Vanes.		Diameter of Inlet Openings.
	Width.	Length.			Width.	Length.	
Ft. Ins.	Ft. Ins.	Ft. Ins.	Ft. Ins.	Ft. Ins.	Ft. Ins.	Ft. Ins.	Ft. Ins.
3 0	0 9	0 9	1 6	4 6	1 1½	1 1½	2 3
3 6	0 10½	0 10½	1 9	5 0	1 3	1 3	2 6
4 0	1 0	1 0	2 0	6 0	1 6	1 6	3 0

Pressure, from 6 ounces to 9 ounces per square inch, and upwards, or 10·4 inches to 15·6 inches of water.

Diameter of Fan.	Vanes. Width.	Vanes. Length.	Diameter of Inlet Openings.	Diameter of Fan.	Vanes. Width.	Vanes. Length.	Diameter of Inlet Openings.
3 0	0 7	1 0	1 0	4 6	0 10½	1 4½	1 9
3 6	0 8½	1 1½	1 3	5 0	1 0	1 6	2 0
4 0	0 9½	1 3½	1 6	6 0	1 2	1 10	2 4

Guibal's fan, for mine ventilation, has blades which are straight, except at the outer ends, which curve forwards. The blades are fixed at a back inclination,—usually 45°—to the radius. The wheel is closely surrounded, for about two-thirds of the circumference, by a casing of brickwork. For the remaining third, the casing gradually opens out into the discharge vent, which expands upwards as an inverted frustum of a cone. A Guibal fan working at Staveley colliery, is 30 feet in diameter, 10 feet wide, it makes 60 revolutions per minute, with the following results of performance :—

Speed in Turns per Minute.	Draft in Inches of Water.	Volume of Air Discharged per Minute.	Efficiency, in parts of the Gross Indicator Power of the Engine.
Turns.	Inches.	Cubic Feet.	Per cent.
32	·70	42[illegible]	40·4
51	1·70	[illegible]	43·1
64	2·77	[illegible]	53·3
68	3·10	[illegible]	53·8

COMPRESSED AIR.

Compressed or Expanded Isothermally.

Air when compressed or expanded under a uniform temperature, or isothermally, follows the hyperbolic law, according to which the pressure varies inversely as the volume.

The total net work for one stroke of the compressor of dry atmospheric air, isothermally, is found by the formula :—

$$W = P\,(V + v)\text{ hyp. log. }\frac{V + v}{V' + v} - (P' - P)\,v \quad . \qquad (1)$$

The total net work of dry air for one stroke of a compressed air engine isothermally expanded in the cylinder down to atmospheric pressure, is given by formula :—

$$W = P\,(V + v)\text{ hyp. log. }\frac{V' + v}{V + v} - (P - P')\,v \quad . \qquad (2)$$

The formulas (1) and (2) are identical in construction.

In cases where the back pressure P'' is less than P', the terminal positive pressure, the total net work is given by formula :—

$$W = P\,(V + v)\text{ hyp. log. }\frac{V' + v}{V + v} - P''\,V' + P\,V \quad . \qquad (3)$$

P = total pressure of air, in pounds per square foot.

V = volume of air, in cubic feet.

v = volume of clearance at each end of cylinder, in cubic feet.

W = work done, in foot pounds.

In practice, the temperature is not uniform, but rises with compression, and falls with expansion : requiring more work for compression, and less work by expansion, than are provided in the above formulas. But these differences are minimised by the application of cooling agents, as cold water surrounding the working cylinder.

In compressing dry air at 62° F. in a non-conducting vessel, adiabatically, to two atmospheres of pressure, the temperature is raised to 178° F. ; and the fall to 62°, in a reservoir, involves a loss of 116°, which is a loss of 18 per cent. of the maximum absolute temperature, or 18 per cent. of efficiency for work.

TABLE 318.—PRESSURE AND VOLUME OF COMPRESSED AIR.

(Adapted from Mr. Shone's Table.)

Pressure above Atmosphere.			Comparative Volume of Air after Compression. Initial Volume=1.		Temperature by Adiabatic Compression, that of the Free Air being 60° F.	Rate of Compression Isothermally.	Average Load against Compressing Piston, per Square Inch.	
			Isothermally.	Adiabatically.			Isothermally.	Adiabatically.
Lbs. per Sq. In.	Inches of Mercury.	Feet of Water.	Volume.	Volume.	Fahr.	Compression.	Load.	Load.
1	2·041	2·31	0·936	0·954	70·04	1·0680	0·967	0·976
2	4·082	4·61	0·880	0·913	79·64	1·1361	1·876	1·910
3	6·123	6·92	0·831	0·876	88·84	1·2041	2·730	2·805
4	8·164	9·23	0·786	0·843	97·68	1·2721	3·538	3·664
5	10·205	11·54	0·746	0·812	106·18	1·3401	5·303	4·491
6	12·246	13·84	0·710	0·784	114·39	1·4081	5·031	5·288
7	14·287	16·15	0·677	0·758	122·32	1·4762	5·725	6·060
8	16·328	18·46	0·648	0·735	129·99	1·5442	6·387	6·806
9	18·369	20·76	0·620	0·713	137·43	1·6122	7·021	7·529
10	20·410	23·07	0·595	0·692	144·65	1·6803	7·629	8·232
11	22·451	25·38	0·572	0·673	151·66	1·7483	8·212	8·914
12	24·492	27·68	0·551	0·655	158·48	1·8164	8·774	9·578
13	26·533	29·99	0·531	0·638	165·13	1·8844	9·315	10·224
14	28·574	32·30	0·512	0·622	171·60	1·9524	9·836	10·854
15	30·615	34·61	0·495	0·607	177·92	2·0204	10·338	11·468
16	32·656	36·91	0·479	0·593	184·09	2·0884	10·825	12·068
17	34·697	39·22	0·464	0·579	190·11	2·1565	11·297	12·654
18	36·738	41·53	0·450	0·567	196·01	2·2245	11·753	13·227
19	38·779	43·83	0·436	0·555	201·77	2·2925	12·193	13·788
20	40·820	46·14	0·424	0·544	207·42	2·3605	12·623	14·337
21	42·861	48·45	0·412	0·533	212·95	2·4286	13·044	14·875
22	44·902	50·75	0·401	0·522	218·37	2·4966	13·450	15·403
23	46·943	53·06	0·390	0·512	223·69	2·5646	13·844	15·921
24	48·984	55·37	0·380	0·503	228·91	2·6327	14·230	16·429
25	51·025	57·68	0·370	0·494	234·03	2·7007	14·604	16·927
26	53·066	59·98	0·361	0·485	239·07	2·7687	14·970	17·419
27	55·107	62·29	0·353	0·477	244·02	2·8367	15·327	17·898
28	57·148	64·60	0·344	0·469	248·88	2·9048	15·676	18·371
29	59·189	66·90	0·336	0·461	253·66	2·9728	16·016	18·837
30	61·230	69·21	0·329	0·454	258·37	3·0408	16·348	19·294
31	63·271	71·52	0·322	0·447	263·00	3·1088	16·673	19·745
32	65·312	73·82	0·315	0·440	267·56	3·1769	16·992	20·190
33	67·353	76·13	0·308	0·434	272·05	3·2449	17·303	20·626
34	69·394	78·44	0·302	0·427	276·48	3·3129	17·608	21·056
35	71·435	80·75	0·296	0·421	280·84	3·3810	17·907	21·480
36	73·476	83·05	0·290	0·415	285·14	3·4490	18·200	21·899
37	75·517	85·36	0·284	0·409	289·38	3·5170	18·487	22·312
38	77·558	87·67	0·279	0·404	293·56	3·5850	18·768	22·718
39	79·599	89·97	0.274	0·399	297·68	3·6531	19·045	23·121
40	81·640	92·28	0·269	0·393	301·75	3·7211	19·316	23·516
41	83·681	94·59	0·264	0·388	305·77	3·7891	19·581	23·908
42	85·722	96·89	0·259	0·383	309·74	3·8571	19·844	24·293
43	87·763	99·20	0·255	0·379	313·66	3·9252	20·101	24·675
44	89·804	101·51	0·250	0·374	817·53	8·9932	20·353	25·052
45	91·845	103·82	0·246	0·370	321·36	4·0612	20·602	25·424
46	93·686	106·12	0·242	0·365	325·13	4·1293	20·846	25·729
47	95·927	108·43	0·238	0·361	328·87	4·1973	21·086	26·155
48	97·968	110·74	0·234	0·357	332·56	4·2653	21·323	26·515
49	100·009	113·04	0·231	0·353	336·21	4·3333	21·555	26·870
50	102·050	115·35	0·227	0·349	339	·4014	21·784	27·221

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The following table shows the corresponding loss of efficiency for several pressures :—

TABLE 319.—LOSS OF EFFICIENCY OF COMPRESSED AIR.

Pressure.	Final Temperature for Compression.	Reduced Efficiency, Initial Temperature for Work, 62° F.	Loss of Efficiency.
Atmospheres.	° Fahr.	Per cent.	Per cent.
2	178	82	18
3	258	73	27
4	321	67	33
5	373	63	37
10	559	51	49

Taking the efficiency of the compressor, and also that of the power-engine, at 80 per cent., the resultant efficiency of the combined compressor and engine, working to 10 atmospheres is $\left(\frac{80\times 80}{100}\times 51=\right)$ 33 per cent. Working to two atmospheres, the resultant efficiency is 52 per cent. In general practice, the resultant efficiency rarely exceeds 30 per. cent.

Table 318 shows the relation of pressure, volume, and temperature, with the load against a compressing piston.

Table 320 shows the net horse-power required for compressing atmospheric air, under pressures of from 2 to 20 atmospheres, calculated by means of formula (1); on the assumption that the temperature is maintained uniformly at 62° F.

The same table shows, reversely, the horse-power developed by compressed air introduced into the cylinder at the various pressures ; on the assumption that the temperature is uniformly 62° F., and that the air is expanded down to atmospheric pressure at the end of the stroke. But, when the air is exhausted, at a pressure higher than that of the atmosphere, the difference of the initial work $P\,V$ and the work of back pressure, $P''\,V'$, is to be added to the work as calculated by formula (3).

Flow of Compressed Air through Pipes.

The head, or difference of the pressures at the beginning and end of a long pipe, through which compressed air is forced, may be taken to vary as the length of the pipe, as the square of the velocity, and inversely as the diameter. According to some authorities, it varies also with the density of the air ; according to others it does not so vary. In Table 321 are given the results of observations made on the flow of compressed air in pipes at the St. Gothard tunnel.

TABLE 320.—NET POWER REQUIRED TO COMPRESS AIR AT THE UNIFORM TEMPERATURE 62° F.

Atmospheres of Pressure, and Ratio of Expansion. 1 Atmosphere=1.		Pressure per Square Inch (approximate).	Horse Power per Cubic Foot of Compressed Air per Minute.	Volume of Compressed Air per Minute per Horse Power, at 62° F.	Equivalent Volume of Free Air, under one Atmosphere, at 62° F.
	Hyperbolic Logarithm of Ratio of Expansion.	Lbs.	H. P.	Cubic Feet.	Cubic Feet.
2	·6931	30	·0889	11·25	22·50
3	1·0986	45	·2114	4·73	14·19
4	1·3863	60	·3556	2·88	11·52
5	1·6094	75	·516	1·94	9·70
6	1·7918	90	·690	1·450	8·70
7	1·9459	105	·874	1·145	8·01
8	2·0794	120	1·067	·938	7·50
9	2·1972	135	1·268	·788	7·09
10	2·3026	150	1·477	·667	6·67
11	2·3979	165	1·692	·591	6·50
12	2·4849	180	1·913	·523	6·28
13	2·5649	195	2·139	·468	6·08
14	2·6391	210	2·369	·422	5·91
15	2·7084	225	2·606	·384	5·76
16	2·7726	240	2·845	·352	5·63
17	2·8332	255	3·089	·324	5·51
18	2·8904	270	3·336	·300	5·40
19	2·9444	285	3·587	·279	5·30
20	2·9957	300	3·843	·260	5·20

At the Mont Cenis tunnel, compressed air of 5·70 atmospheres of pressure was reduced to 5·50 atmospheres, or by 3½ per cent. of the head, in a 7⅝ inch cast-iron pipe 1775 yards in length, comprising leakage and frictional resistance; whilst 64 cubic feet of compressed air was delivered per minute. In a length of 6,666 yards of pipe, the loss was 5 per cent. of the initial pressure.

The Table 322 of loss of pressure by friction in pipes, has been issued by the Rand Drill Company. The calculated quantities are those for straight pipes. To make ample allowance for heads, elbows, and tees, one size of pipe larger than the tabular size may be taken.

TABLE 321.—LOSS OF PRESSURE IN COMPRESSED-AIR PIPE-MAIN, AT ST. GOTHARD TUNNEL.

(E. Stockalper.)

Experiment.	Air Main.		Volume per Second of Free Air, or Equivalent Volume at Atmospheric Pressure and 32° F.	Volume per Second of Compressed Air at Mean Density.	Mean Density of Compressed Air. (Water = 1)	Weight of Air Flowing per Second.	Mean Velocity in Feet per Second.	Mean Temperature in Main.	Observed Pressures.			
	Diameter.	Length.							Pressure at Beginning of Pipe.	Pressure at End of Pipe.	Loss of Pressure.	
No.	Inches.	Feet.	Cubic Feet.	Cub. Ft.	Density.	Lbs.	Feet.	° Fahr.	Atmos.	Atmos.	Atmos.	Per Cent.
1	7·87	15,092	33·056	6·534	·00650	2·669	19·32	70	5·60	5·24	0·36	6·4
	5·91	1,712·6		7·063	·00603	2·669	37·14	80	5·24	5·00	0·24	4·6
2	7·87	15,092	22·002	5·509	·00514	1·776	16·30	70	4·35	4·13	0·22	5·1
	5·91	1,712·6		5·863	·00482	1·776	...	80	4·13	...	...	...
3	7·87	15,042	18·364	5·262	·00449	1·483	15·58	70	3·84	3·65	0·19	5·0
	5·91	1,712·6		5·580	·00423	1·483	29·34	80	3·65	3·54	0·11	3·0

TABLE 322.—LOSS OF PRESSURE BY FRICTION OF COMPRESSED AIR IN PIPES.

(F. A. Halsey.)

Diameter of Pipe.	Cubic Feet of Free Air compressed to a Gauge Pressure of 60 lbs. per Square Inch, and passing through the Pipe per Minute.																			
	50	75	100	125	150	200	250	300	400	600	800	1000	1200	1500	1800	2000	2500	3000	4000	5000
	Loss of Pressure in Pounds per Square Inch for each 1,000 Feet of Straight Pipe.																			
Ins.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
1	10·40	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
1¼	2·63	5·90	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
1½	1·22	2·75	4·89	7·65	11·00	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
2	·35	·79	1·41	2·20	3·17	5·64	8·78	...	...	...	...	...	...	...	...	...	...	...	...	...
2½	·14	·32	·57	·90	1·29	2·30	3·58	5·18	9·20	...	...	...	...	...	...	...	...	...	...	...
3	...	·11	·20	·31	·44	·78	1·23	1·77	3·14	7·05	...	...	...	...	...	...	...	...	...	...
3½	...	...	...	·15	·21	·38	·59	·85	1·51	3·40	5·03	...	...	...	...	...	...	...	...	...
4	...	...	...	...	...	·20	·31	·45	·80	1·81	3·22	5·02	7·23	11·30	...	...	...	...	...	...
5	...	...	...	...	...	...	·10	·15	·26	·59	1·04	1·63	2·35	3·66	5·28	6·50	10·20	...	...	...
6	...	...	...	...	...	...	...	...	...	·23	·41	·64	·93	1·46	2·09	2·59	4·06	5·81	10·30	...
8	...	...	...	...	...	...	...	...	...	...	·10	·16	·23	·37	·53	·65	1·02	1·47	2·61	4·08
10	...	...	...	...	...	...	...	...	...	...	...	...	...	·12	·17	·21	·33	·47	·84	1·30
12	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	·13	·19	·34	·53
14	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	[illegible]	[illegible]	[illegible]	[illegible]

REFRIGERATING MACHINERY.

For the cooling of brine and other liquids by the alternate compression and expansion of air, Mr. David Thomson gives the following formulæ, in which the machine is supposed to be perfect :—

$$P = 772\ C \times \frac{T - T'}{T} \quad . \quad . \quad . \quad (1)$$

$$C = \frac{P}{772} \times \frac{T}{T - T'} \quad . \quad . \quad . \quad . \quad (2)$$

P = power required to do the cooling work C, in foot-pounds.

C = cooling work done, in thermal units.

T = Absolute maximum temperature, Fahrt., of the air in the hot or compression end of the cooling machine.

T′ = absolute minimum temperature, Fahrt., of the air in the cold or expansion end of the machine.

These formulæ indicate that the most economical results, as regards consumption of power, are obtained when the machine is worked within a small range of temperature, as in breweries, where the temperature of water is frequently to be lowered only 10° F.

These formulæ are applicable to all cooling machines, whether they operate by means of air, ether, ammonia, or any other fluid. In the ammonia machine, or other machine working on the same principle, in which no mechanical power is applied, the value of P, it is understood, is the heat theoretically required, at the rate of 1 heat-unit for 772 foot-pounds of power ; and the formula (1) becomes :—

(Ammonia). Heat required to do the work $C = C \frac{T - T_1}{T_1} \quad . \quad (3)$

The ammonia machine has, theoretically, a great economical superiority, as heat is so much less expensive than its equivalent of mechanical power.

The nature of the vapour employed affects the size of the machine ; the relative capacity of cylinder required being :—

Ammonia	1	Methyl ether	1·8
Carbonic acid	0·16	Sulphurous acid	2·6
Methyl chloride	1·8	Ether	15·1

HOT-AIR ENGINES.

In Rider's Hot-air Engine, called a compression engine, two single-acting cylinders are placed vertically, side by side, connected at the upper part by a regenerator composed of thin plates. One of those is the working or hot cylinder, under which a fire is maintained; the other is the air-pump, or cold cylinder, surrounded by water to cool the air which is drawn into it, and which is pumped into the hot cylinder. The plungers of the cylinders are worked by cranks forming an angle of 95°, on a shelf overhead. The 1-horse-power engine has 6¾-inch plungers, with strokes of 9½ inches hot, and 8·6 inches cold. At a speed of 120 turns per minute, the effective mean pressure in the hot cylinder was 16·8 lbs. per square inch; and in the cold cylinder 7·15 lbs.; leaving 10·33 lbs. net effective pressure on the hot plunger, making 1·076 horse-power. It is stated that the coal consumed was at the rate of from 2lbs. to 3lbs. per net indicator horse-power.

In Benier's Hot-Air Engine, the air is heated within the working cylinder by means of a furnace within the cylinder. All the heat of combustion is directly utilised; the valves are only traversed by cold air; and the heated air acts directly as it expands on the piston. It is stated that the consumption of coke is at the rate of 3·3 pounds per horse-power per hour for motors of 4 horse-power; and 4 pounds for motors of 2 horse-power.

WATER POWER.

Flow of Water.

The flow of water by the action of gravity, if there be no deduction from the force, is according to the formula,—

$$v = 8\sqrt{h} \quad . \quad . \quad . \quad . \quad . \quad . \qquad (1)$$

v = velocity in feet per second.

h = height of fall in feet.

The velocity of water discharged through the side of a vessel is variously affected by the form of the ajutage. In parts of the theoretical velocity v, as above, the velocity varies thus :—

	Per cent.
With internal tube	50
Thin plate only	62
Nozzle, 2 diameters in length	82
Converging cone, length 2½ diameters	95
Vena contracta, length ½ diameter of orifice Smallest diameter ·785 diameter of orifice	160
Diverging cone, length 9 diameters	146

The velocity of flow of water in a full smooth cast-iron pipe of uniform diameter, is given by the formula ;—(Hawksley).

$$v=48\sqrt{\frac{h}{l}\times d} \qquad (2)$$

Mr. Downing employs the same formula with the co-efficient 50 instead of 48. His formula for the quantity of water discharged from a channel or pipe is,—

$$Q=100a\sqrt{\frac{h}{l}\times D} \qquad (3)$$

v = velocity, in feet per second.
h = head, in feet.
l = length, in feet.
d = diameter, in feet.
c = wetted perimeter, in feet.
a = sectional area of current, in square feet.
Q = quantity of water discharged, in cubic feet per second.
$D=\frac{a}{c}$ = hydraulic mean depth.

By the aid of Table 323, based on formula (3), the discharge, the diameter of pipe, and the fall are readily calculable.

1. *To find the rate of discharge*, when the length, fall, and diameter of pipe in feet are given. Divide the tabular number next the diameter by the square root of the rate of inclination. The quotient is the rate of discharge in cubic feet per minute.

2. *To find the required diameter*, when the length and fall in feet, and the rate of discharge in cubic feet per minute, are given. Multiply the rate of discharge by the square root of the rate of inclination ; find the product or the nearest value to it in the table. The diameter next to it is the diameter required, in feet.

3. *To find the required fall*, when the length and diameter

in feet, and the rate of discharge in cubic feet per minute are given. Divide the tabular number next the given diameter by the rate of discharge; square the quotient, and divide it by the length of pipe. The final quotient is the fall in feet.

Note.—The rate of inclination is the quotient of the length by the vertical height.

Half the tabular number may be taken to find approximately the discharge for pipes half-full. The calculation is also available for sewers and the like.

TABLE 323.—DISCHARGE OF WATER IN PIPES.

(Turnbull.)

Diameter of Pipes.	Tabular Number.	Diameter of Pipes.	Tabular Number	Diameter of Pipes.	Tabular Number.
Inches.		Inches.		Inches.	
1	4·7	21	9544	42	53994
1½	13·0	22	10717	43	57250
2	26·4	23	11971	44	60625
3	73·6	24	13327	45	64142
4	150·7	25	14753	46	67770
5	262·9	26	16267	47	71494
6	416·5	27	17881	48	75391
7	611·4	28	19523	51	87713
8	852·8	29	21375	54	101190
9	1147·7	30	23282	57	115844
10	1492·1	31	25263	60	131700
11	1892	32	27335	66	167134
12	2356	33	29545	72	207752
13	2875	34	31826	78	253764
14	3459	35	34208	84	305384
15	4115	36	36726	90	362871
16	4806	37	39319	96	426436
17	5621	38	42018	102	496220
18	6492	39	44861	108	572343
19	7259	40	47674	114	655124
20	8439	41	58811	120	745014

Discharge of Water through Fire-hose and Nozzles.

In Tables 326 and 327, are given the actual discharge of water through small nozzles and ring-nozzles connected to 2½-inch hose, 50 feet and 100 feet long.

In Table 328, are given the loss of head by friction in fire-hose, of rubber and of leather, under given heads and rates of discharge.

TABLE 324.—PRESSURE OF WATER FOR GIVEN HEADS.

Head.	Pressure per Square Inch.	Head.	Pressure per Square Inch.	Head.	Pressure per Square Inch.	Head.	Pressure per Square Inch.
Feet.	Pounds.	Feet.	Pounds.	Feet.	Pounds.	Feet.	Pounds.
1	0·43	41	17·75	81	35·08	121	52·41
2	0·86	42	18·19	82	35·52	122	52·84
3	1·30	43	18·62	83	35·05	123	53·28
4	1·73	44	19·05	84	36·39	124	53·71
5	2·16	45	19·49	85	36·82	125	54·15
6	2·59	46	19·92	86	37·25	126	54·58
7	3·03	47	20·35	87	37·68	127	55·01
8	3·46	48	20·79	88	38·12	128	55·44
9	3·89	49	21·22	89	38·55	129	55·88
10	4·33	50	21·65	90	38·98	130	56·31
11	4·76	51	22·09	91	39·42	131	56·74
12	5·20	52	22·52	92	39·85	132	57·18
13	5·63	53	22·95	93	40·28	133	57·61
14	6·06	54	23·39	94	40·72	134	58·04
15	6·49	55	23·82	95	41·15	135	58·48
16	6·93	56	24·26	96	41·58	136	58·91
17	7·36	57	24·69	97	42·01	137	59·34
18	7·79	58	25·12	98	42·45	138	59·77
19	8·22	59	25·55	99	42·88	139	60·21
20	8·66	60	25·99	100	43·31	140	60·64
21	9·09	61	26·42	101	43·75	141	61·07
22	9·53	62	26·85	102	44·18	142	61·51
23	9·96	63	27·29	103	44·61	143	61·94
24	10·39	64	27·72	104	45·05	144	62·37
25	10·82	65	28·15	105	45·48	145	62·81
26	11·26	66	28·58	106	45·91	146	63·24
27	11·69	67	29·02	107	46·34	147	63·67
28	12·12	68	29·45	108	46·78	148	64·10
29	12·55	69	29·88	109	47·21	149	64·54
30	12·99	70	30·32	110	47·64	150	64·97
31	13·42	71	30·75	111	48·08	151	65·40
32	13·86	72	31·18	112	48·51	152	65·84
33	14·29	73	31·62	113	48·94	153	66·27
34	14·72	74	32·05	114	49·38	154	66·70
35	15·16	75	32·48	115	49·81	155	67·14
36	15·59	76	32·92	116	50·24	156	67·57
37	16·02	77	33·35	117	50·68	157	68·00
38	16·45	78	33·78	118	51·11	158	68·43
39	16·89	79	34·21	119	51·54	159	68·87
40	17·32	80	34·65	120	51·98	160	69·31

TABLE 324.—PRESSURE OF WATER FOR GIVEN HEADS (*continued*).

Head.	Pressure per Square Inch.	Head.	Pressure per Square Inch.	Head.	Pressure per Square Inch.	Head.	Pressure per Square Inch.
Feet.	Pounds.	Feet.	Pounds.	Feet.	Pounds.	Feet.	Pounds.
161	69·74	200	86·63	239	103·53	278	120·42
162	70·17	201	87·07	240	103·96	279	120·85
163	70·61	202	87·50	241	104·39	280	121·29
164	71·04	203	87·93	242	104·83	281	121·72
165	71·47	204	88·36	243	105·26	282	122·15
166	71·91	205	88·80	244	105·69	283	122·59
167	72·34	206	89·23	245	106·13	284	123·02
168	72·77	207	89·66	246	106·56	285	123·45
169	73·20	208	90·10	247	106·99	286	123·89
170	73·64	209	90·53	248	107·43	287	124·32
171	74·07	210	90·96	249	107·86	288	124·75
172	74·50	211	91·39	250	108·29	289	125·18
173	74·94	212	91·83	251	108·73	290	125·62
174	75·37	213	92·26	252	109·16	291	126·05
175	75·80	214	92·69	253	109·59	292	126·48
176	76·23	215	93·13	254	110·03	293	126·92
177	76·67	216	93·56	255	110·46	294	127·35
178	77·10	217	93·99	256	110·89	295	127·78
179	77·53	218	94·43	257	111·32	296	128·22
180	77·97	219	94·86	258	111·76	297	128·65
181	78·40	220	95·30	259	112·19	298	129·08
182	78·84	221	95·73	260	112·62	299	129·51
183	79·27	222	96·16	261	113·06	300	129·95
184	79·70	223	96·60	262	113·49	310	134·28
185	80·14	224	97·03	263	113·92	320	134·62
186	80·57	225	97·46	264	114·36	330	142·95
187	81·00	226	97·90	265	114·79	340	147·28
188	81·43	227	98·33	266	115·22	350	151·61
189	81·87	228	98·76	267	115·66	360	155·94
190	82·30	229	99·20	268	116·09	370	160·27
191	82·73	230	99·63	269	116·52	380	164·61
192	83·17	231	100·06	270	116·96	390	168·94
193	83·60	232	100·49	271	117·39	400	173·27
194	84·03	233	100·93	272	117·82	500	216·58
195	84·47	234	101·36	273	118·26	600	259·90
196	84·90	235	101·79	274	118·69	700	302·22
197	85·33	236	102·23	275	119·12	800	346·54
198	85·76	237	102·66	276	119·56	900	389·86
199	86·20	238	103·09	277	119·99	1000	433·18

TABLE 325.—FLOW OF WATER THROUGH CLEAN CAST-IRON PIPES, AND
BY FRICTION, FOR EACH 100 FEET LENGTH OF PIPE. (Based on Ellis and Howland's experiments.)

Velocity in Feet per Second.	DIAMETER OF PIPES, IN INCHES.																			
	3		4		5		6		7		8		9		10		12		14	
	Discharge per Minute in Cubic Feet, and Loss of Head in Feet, per 100 Feet long.																			
Feet.	Cubic Feet.	Feet of Head.	Cubic Feet.	Feet of Head	Cubic Feet.	Feet of Head.	Cubic Feet.	Feet of Head.	Cubic Feet.	Feet of Head.	Cubic Feet.	Feet of Head.	Cubic Feet.	Feet of Head.	Cubic Feet.	Feet of Head.	Cubic Feet.	Feet of Head	Cubic Feet.	Feet of Head
2	5·9	·97	10·5	·55	16·4	·41	23·6	·32	32	·27	42	·23	53	·19	65	·18	94	·15	128	·12
2·5	7·3	1·49	13	·12	20·4	·64	29·3	·50	40	·43	52	·36	66	·30	82	·27	117	·23	160	·19
3	8·8	1·9	15·7	1·2	24·5	·82	35·2	·72	48	·61	63	·51	79	·44	98	·39	141	·33	192	·27
3·5	10·3	2·6	18·3	1·6	28·6	1·2	41·2	1·0	56	·7	73	·71	93	·61	115	·52	165	·45	224	·37
4	11·8	3·3	21	2·2	32·7	1·7	47	1·3	64	·9	84	·92	106	·79	131	·69	188	·59	257	·49
4·5	...	...	...	...	...	...	53	1·6	72	1·2	94	1·2	119	1·01	147	·87	212	·75	288	·61
5	...	...	...	...	...	...	...	...	...	...	...	...	133	1·2	164	1·1	235	·90	320	·76
5·5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	352	·92
6	..	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...

	15		18		21		24		27		30		33		36		42		48	
Feet.	Cubic Feet.	Feet of Head.	Cubic Feet.	Feet of Head.	Cubic Feet.	Feet of Head.	Cubic Feet.	Feet of Head.	Cubic Feet.	Feet of Head.	Cubic Feet.	Feet of Head.	Cubic Feet.	Feet of Head.	Cubic Feet.	Feet of Head.	Cubic Feet.	Feet of Head.	Cubic Feet.	Feet of Head.
2	148	·11	212	·095	288	·075	377	·065	478	·055	590	·052	710	·049	850	·047	1150	·036	1500	·030
2·5	184	·17	264	·147	360	·117	470	·109	595	·088	730	·085	890	·076	1000	·067	1440	·056	1880	·046
3	220	·25	317	·21	430	·17	565	·15	715	·13	880	·12	1070	·108	1270	·10	1730	·081	2250	·067
3·5	258	·34	372	·29	505	·23	660	·20	835	·18	1030	·16	1250	·15	1480	·14	2020	·111	2630	·092
4	295	·44	425	·36	575	·31	755	·27	955	·23	1180	·22	1420	·20	1700	·17	2300	·14	3000	·116
4·5	331	·56	475	·46	650	·39	845	·34	1070	·30	1320	·28	1600	·25	1900	·22	2590	·18	3380	·15
5	368	·70	530	·58	720	·48	940	·41	1190	·37	1470	·34	1780	·30	2120	·27	2880	·22	3750	·18
5·5	405	·84	580	·70	790	·59	1030	·50	1310	·44	1610	·39	1950	·36	2330	·32	3170	·27	4130	·22
6	...	...	...	...	...	...	1130	·59	1430	·53	1760	·49	2140	·43	2540	·4	3450	·32	4500	·27

TABLE 326.—WATER DISCHARGED FROM NOZZLES ATTACHED TO 50 FEET OF 2½-INCH HOSE. (Freeman.)

Hydrant Pressure.	1⅜-Inch Smooth Nozzle.			1¼-Inch Smooth Nozzle.			1⅛-Inch Smooth Nozzle.			1-Inch Smooth Nozzle.			⅞-In. Smooth Nozzle or 1-Inch Ring Nozzle.			¾-In. Smooth Nozzle or ⅞-Inch Ring Nozzle.			1⅜-Inch Ring Nozzle.			1¼-Inch Ring Nozzle.			1⅛-Inch Ring Nozzle.			Hydrant Pressure.
	Gals. per Min.			Gals. per Min.			Gals. per Min.			Gals. per Min.			Gals. per Min.			Gals. per Min.			Gals. per Min.			Gals. per Min.			Gals. per Min.			
Lbs. per Sq. Inch.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose." Inside rough.	Ordinary best quality Rubber-lined Hose. Inside smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose." Inside rough.	Ordinary best quality Rubber-lined Hose. Inside smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose." Inside rough.	Ordinary best quality Rubber-lined Hose. Inside smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose." Inside rough.	Ordinary best quality Rubber-lined Hose. Inside smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose." Inside rough.	Ordinary best quality Rubber-lined Hose. Inside smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose." Inside rough.	Ordinary best quality Rubber-lined Hose. Inside smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose." Inside rough.	Ordinary best quality Rubber-lined Hose. Inside smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose." Inside rough.	Ordinary best quality Rubber-lined Hose. Inside smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose." Inside rough.	Ordinary best quality Rubber-lined Hose. Inside smooth.	Lbs. per Sq. Inch.
5	75	78	86	67	68	75	58	59	63	49	49	52	39	39	40	30	30	31	63	63	70	55	56	58	47	47	49	5
10	106	109	122	95	97	106	83	84	89	69	70	73	55	56	57	42	42	43	90	92	98	78	80	84	67	68	70	10
15	129	133	149	117	119	129	101	103	109	84	85	88	68	68	70	51	51	52	110	113	120	96	98	103	82	83	86	15
20	150	154	172	134	137	149	117	118	126	98	98	103	78	78	80	59	59	60	127	129	139	111	113	119	94	95	99	20
25	168	173	192	150	153	167	130	132	141	109	110	114	87	88	89	66	67	68	142	145	156	124	126	133	105	107	111	25
30	183	188	209	164	168	183	143	144	153	119	120	125	95	96	98	72	73	73	156	159	171	136	138	146	115	117	121	30
35	198	204	227	178	182	197	153	157	166	128	130	135	103	103	106	78	78	79	167	172	184	147	149	158	124	126	131	35
40	212	218	243	189	194	211	164	168	178	138	139	144	110	111	113	83	83	84	179	183	198	157	159	168	133	135	140	40
45	225	232	258	201	206	224	174	178	188	146	147	153	117	118	120	89	89	90	191	194	209	167	169	171	141	143	148	45
50	237	244	271	213	217	236	181	187	198	153	155	162	123	123	127	93	93	94	201	204	220	176	178	189	149	151	157	50
55	248	256	284	223	228	247	193	196	209	161	163	170	128	129	132	98	98	99	211	214	231	184	187	198	156	158	164	55
60	259	267	298	233	238	258	202	204	218	168	170	178	134	135	139	102	102	103	220	224	241	193	195	206	163	165	171	60
65	270	278	309	242	247	268	210	213	227	175	178	184	140	141	144	106	106	108	229	233	251	200	203	214	171	172	178	65
70	280	287	321	251	256	278	218	221	234	182	184	192	145	147	150	110	110	112	238	243	261	208	211	223	177	178	185	70
75	290	298	333	259	265	295	225	229	243	188	190	198	151	152	155	114	114	119	246	251	270	215	218	230	183	184	192	75
80	299	308	344	268	278	298	233	237	251	194	197	205	155	157	160	118	119	120	254	259	278	222	225	238	188	190	198	80
85	309	318	354	277	283	308	240	244	258	200	203	211	160	161	165	121	122	123	262	267	288	228	233	245	194	196	203	85
90	318	328	364	285	291	316	247	251	266	206	208	218	164	166	170	124	125	127	269	275	296	235	239	253	199	202	210	90
95	327	336	374	292	298	325	253	258	273	211	214	223	169	170	174	128	128	130	277	282	303	242	246	259	205	208	216	95
100	335	345	383	300	307	333	260	264	281	217	220	229	173	175	179	132	131	134	284	290	312	248	253	266	211	213	222	100

TABLE 374.—WATER DISCHARGED FROM HOSE

Hydrant Pressure.	1⅜-Inch Smooth Nozzle.			1¼ Inch Smooth Nozzle.			1⅛-Inch Smooth Nozzle.			1-Inch Smooth Nozzle.			⅞-In. Smooth Nozzle or 1 Inch Ring Nozzle.			¾-In. Smooth Nozzle or ⅞-Inch Ring Nozzle.			1⅜-Inch Ring Nozzle.			1¼-Inch Ring Nozzle.			1⅛-Inch Ring Nozzle.			Hydrant Pressure.
	Gals. per Min.			Gals. per Min.			Gals. per Min.			Gals. per Min.			Gals. per Min.			Gals. per Min.			Gals. per Min.			Gals. per Min.			Gals. per Min.			
Lbs. per Sq. Inch.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose." Inside rough.	Ordinary best quality Rubber-lined Hose. Inside smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose." Inside rough.	Ordinary best quality Rubber-lined Hose. Inside smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose." Inside rough.	Ordinary best quality Rubber-lined Hose. Inside smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose." Inside rough.	Ordinary best quality Rubber-lined Hose. Inside smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose." Inside rough.	Ordinary best quality Rubber-lined Hose. Inside smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose." Inside rough.	Ordinary best quality Rubber-lined Hose. Inside smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose." Inside rough.	Ordinary best quality Rubber-lined Hose. Inside smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose." Inside rough.	Ordinary best quality Rubber-lined Hose. Inside smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose." Inside rough.	Ordinary best quality Rubber-lined Hose. Inside smooth.	Lbs. per Sq. Inch.
5	63	66	78	58	60	68	52	53	59	45	46	49	37	38	39	28	28	29	56	58	65	50	52	57	43	44	48	5
10	89	93	101	82	85	97	73	76	83	63	65	69	53	53	55	40	41	42	78	81	83	71	73	80	62	63	68	10
15	101	105	133	101	104	119	90	93	103	78	79	85	63	64	68	49	50	51	96	100	113	87	89	98	75	77	83	15
20	126	131	154	116	120	137	104	107	118	89	92	98	73	74	78	57	58	59	111	115	129	100	103	113	88	89	95	20
25	141	147	173	129	134	153	116	119	132	100	102	110	83	83	88	63	64	65	124	128	145	112	115	126	98	99	107	25
30	154	160	188	142	147	168	127	130	144	110	112	120	90	92	96	70	70	73	136	141	159	123	126	138	107	108	117	30
35	167	173	204	153	158	182	138	141	157	119	121	130	98	99	103	75	76	78	147	152	172	133	136	149	116	118	126	35
40	178	185	218	164	170	194	147	151	168	127	128	139	104	106	111	81	81	83	157	163	183	141	145	159	123	126	135	40
45	188	197	232	174	180	206	156	160	178	134	138	148	110	112	118	86	86	88	167	173	194	150	154	169	131	133	143	45
50	199	208	244	183	190	217	164	168	187	142	145	155	116	118	123	90	91	93	176	182	204	156	163	178	138	141	151	50
55	209	218	256	193	199	228	173	177	196	148	152	163	122	123	129	94	95	98	184	191	214	166	170	187	144	148	158	55
60	218	228	267	201	208	238	180	185	204	155	158	170	128	129	135	98	99	102	193	199	224	173	178	195	151	154	165	60
65	227	237	278	209	217	247	188	193	213	162	165	178	133	134	141	103	103	106	201	207	233	181	185	203	158	160	172	65
70	235	245	288	218	225	256	194	200	221	168	171	184	138	139	147	107	108	110	208	215	242	188	192	211	162	166	178	70
75	243	253	298	225	233	266	201	207	229	173	176	190	143	144	152	110	111	114	216	223	251	194	199	218	169	172	184	75
80	251	262	308	232	240	274	208	213	237	179	183	197	148	149	157	114	115	118	223	229	259	200	205	225	174	178	190	80
85	259	270	318	239	248	283	214	220	244	185	188	203	152	154	161	118	119	122	229	237	267	206	212	233	179	183	196	85
90	267	278	328	246	255	291	220	227	251	190	194	208	157	158	166	121	122	125	236	243	274	213	218	239	185	188	202	90
95	274	285	336	253	262	298	227	233	258	195	199	214	160	163	170	124	125	128	243	250	282	218	224	246	190	193	208	95
100	281	293	345	259	268	307	233	239	264	200	204	220	164	167	175	128	128	132	249	257	289	224	229	252	195	198	213	100

TABLE 328.—LOSS OF PRESSURE BY FRICTION PER 100 FEET OF 2½-INCH FIRE-HOSE, FOR GIVEN HEADS AND RATES OF DISCHARGE. (Fanning.)

Head.		Discharge per Minute.	Loss of Head by Friction.		Distances reached by Jet.		Discharge per Minute.	Loss of Head by Friction.		Distances reached by Jet.	
		Diameter of Nozzle in Inches.									
		1 Inch.					1⅛ Inches.				
			Rubber Hose.	Leather Hose.	Horizontal.	Vertical.		Rubber Hose.	Leather Hose.	Horizontal.	Vertical.
Lbs. per Sq. In.	Feet.	Gallons.	Lbs.	Lbs.	Feet.	Feet.	Gallons.	Lbs.	Lbs.	Feet.	Feet.
20	46·2	91·7	4·35	6·33	70	43	115·8	6·79	9·05	71	43
30	69·3	103·3	6·40	8·53	90	62	141·7	10·16	21·71	93	63
40	92·4	129·2	8·40	10·83	109	79	163·3	13·60	16·38	113	81
50	115·5	144·2	10·20	13·10	126	94	182·5	17·05	20·11	132	97
60	138·6	157·5	12·80	15·34	142	108	200·0	20·59	23·88	148	112
70	161·7	170·9	14·80	17·79	156	121	215·8	24·00	27·61	163	125
80	184·8	182·5	17·00	20·11	168	131	230·8	27·00	31·41	175	137
90	207·9	193·3	19·20	22·40	178	140	245·0	30·00	35·24	186	148
100	231·0	204·2	20·50	24·83	186	148	259·3	33·00	39·07	193	157
		1¼ Inches.					1⅜ Inches.				
Lbs. per Sq. In.	Feet.	Gallons.	Lbs.	Lbs.	Feet.	Feet.	Gallons.	Lbs.	Lbs.	Feet.	Feet.
20	46·2	142·5	10·28	12·84	73	43	172·5	15·00	18·81	75	44
30	69·3	175·0	15·64	19·00	96	63	210·8	22·96	26·39	100	65
40	92·4	201·7	20·85	24·07	118	82	244·2	29·40	35·01	124	85
50	115·5	225·8	25·46	30·11	138	99	273·3	40·50	43·38	146	102
60	138·6	247·5	29·50	35·94	156	115	290·8	48·20	52·00	166	118
70	161·7	266·7	39·00	41·57	172	129	322·5	55·70	60·40	184	133
80	184·8	285·0	43·81	47·36	186	142	344·2	64·70	68·59	200	146
90	207·9	302·5	49·42	53·25	198	154	374·2	72·00	76·73	218	158
100	231·0	319·2	55·00	59·20	207	164	385·0	79·30	84·87	234	[illegible]

TABLE 329.—DISCHARGE OF WATER OVER WEIRS IN STREAMS, FOR EACH INCH OF WIDTH.

Depth on Weir.	Discharge per Minute per Inch Wide.	Depth on Weir.	Discharge per Minute per Inch Wide.	Depth on Weir.	Discharge per Minute per Inch Wide.	Depth on Weir.	Discharge per Minute per Inch Wide
Inches.	Cub. Ft.	Inches.	Cub. Ft.	Inches.	Cub. Ft.	Inches.	Cub. Ft.
1	·40	5½	5·18	10	12·71	14½	22·22
1⅛	·43	5⅝	5·36	10⅛	12·83	14⅝	22·51
1¼	·55	5¾	5·54	10¼	13·19	14¾	22·79
1⅜	·65	5⅞	5·72	10⅜	13·43	14⅞	23·08
1½	·74	6	5·90	10½	13·67	15	23·38
1⅝	·83	6⅛	6·00	10⅝	13·93	15⅛	23·53
1¾	·93	6¼	6·28	10¾	14·16	15¼	23·97
1⅞	1·03	6⅜	6·47	10⅞	14·42	15⅜	24·26
2	1·14	6½	6·65	11	14·67	15½	24·56
2⅛	1·19	6⅝	6·85	11⅛	14·79	15⅝	24·86
2¼	1·36	6¾	7·05	11¼	15·18	15¾	25·16
2⅜	1·47	6⅞	7·25	11⅜	15·43	15⅞	25·46
2½	1·59	7	7·44	11½	15·67	16	25·76
2⅝	1·71	7⅛	7·54	11⅝	15·96	16⅛	25·91
2¾	1·83	7¼	7·84	11¾	16·20	16¼	26·36
2⅞	1·96	7⅜	8·05	11⅞	16·46	16⅜	26·66
3	2·09	7½	8·25	12	16·73	16½	26·97
3⅛	2·16	7⅝	8·45	12⅛	16·86	16⅝	27·27
3¼	2·36	7¾	8·66	12¼	17·26	16¾	27·58
3⅜	2·50	7⅞	8·86	12⅜	17·52	16⅞	27·89
3½	2·63	8	9·10	12½	17·78	17	28·20
3⅝	2·78	8⅛	9·20	12⅝	18·05	17⅛	28·35
3¾	2·92	8¼	9·52	12¾	18·32	17¼	28·82
3⅞	3·07	8⅜	9·74	12⅞	18·58	17⅜	29·14
4	3·22	8½	9·96	13	18·87	17½	29·45
4⅛	3·29	8⅝	10·18	13⅛	19·01	17⅝	29·76
4¼	3·52	8¾	10·40	13¼	19·42	17¾	30·08
4⅜	3·68	8⅞	10·62	13⅜	19·69	17⅞	30·39
4½	3·83	9	10·86	13½	19·97	18	30·70
4⅝	3·99	9⅛	10·97	13⅝	20·24	18⅛	30·86
4¾	4·16	9¼	11·31	13¾	20·52	18¼	31·34
4⅞	4·32	9⅜	11·54	13⅞	20·80	18⅜	31·66
5	4·50	9½	11·77	14	21·09	18½	31·98
5⅛	4·58	9⅝	12·00	14⅛	21·23	18⅝	32·31
5¼	4·84	9¾	12·23	14¼	21·65	18¾	32·63
5⅜	5·01	9⅞	12·47	14⅜	21·94	18⅞	32·96

Measurement of Water in a Stream.

To measure the volume of water flowing past a given point in a stream per minute, select a portion of the stream, uniform or nearly uniform in width, throw into the middle of the stream, a floating body sufficiently heavy to be almost totally immersed, as a bottle partly filled with water, and note the time taken to float from one mark to another; or, note the distance traversed by the float in one minute. The observation should be repeated several times to give an average result. Measure several sections of the stream within the measured distance, and multiply the average area in square feet by the distance in feet. From the volume thus calculated, one-fifth is deducted, as an allowance for retardation by frictional resistance at the bottom and sides, to give the volume of flow in cubic feet per minute.

Another method of measurement, admitting of more nearly exact results, is to cause the water to flow over a weir, by fixing a board across the stream where it flows slowly, having a notch cut into it broad enough and deep enough for all the water to pass over and fall freely. At the distance of a yard or two from the notch, up-stream, fix a rod, and mark on it the level of the crest of the notch, measure the height of the water surface above this mark, to give the depth of the crest below the surface of the water. Find in the Table 329, calculated according to Du Buat's formula, the observed depth in inches, and multiply it by the corresponding value in the next column, which expresses the volume discharged for each inch in width of the crest. The product is the whole volume of water discharged in cubic feet per minute.

For example, if the depth over a weir 50 inches wide be 6½ inches, find 6½ inches in the columns of depths, and note in the next column the quantity of water, 6·65 cubic feet per inch wide per minute. Multiply 6·65 by 50; the product is 332·5 cubic feet, the volume discharged per minute.

Discharge of Water from a Tank over a Tumbling Bay.

Messrs. B. Donkin & Co. have made observations of the quantity of water discharged from a tank, over a rectangular notch, tumbling bay or weir, cut into a brass or copper sheet, ⅛ inch thick, fastened to the inside of the tank. The bay was 6 inches wide. The levels of water were observed on the same system as already described for the measurement of streams. The width of the bay should not in any case be greater than one-third of the width of the tank. Table 330 gives the weight and volume of water falling over a bay 6 inches wide, in one minute, for depths of from $1\frac{1}{2}$ inches to $4\frac{15}{16}$ inches over the bay.

For bays of greater width than 6 inches, the rate of discharge is increased in the same proportion.

TABLE 330.—QUANTITY OF WATER DISCHARGED OVER A TUMBLING BAY, 6 INCHES WIDE.

(Donkin.)

Depth over Tumbling Bay.	Water per Minute.		Depth over Tumbling Bay.	Water per Minute.	
Inches.	Pounds.	Cub. Ft.	Inches.	Pounds.	Cub. Ft.
$1\frac{1}{2}$	274	4·39	$3\frac{1}{4}$	874	14·00
$1\frac{9}{16}$	292	4·67	$3\frac{5}{16}$	900	14·43
$1\frac{5}{8}$	310	4·96	$3\frac{3}{8}$	926	14·83
$1\frac{11}{16}$	327	5·24	$3\frac{7}{16}$	951	15·24
$1\frac{3}{4}$	345	5·52	$3\frac{1}{2}$	977	15·65
$1\frac{13}{16}$	365	5·84	$3\frac{9}{16}$	1003	16·08
$1\frac{7}{8}$	383	6·13	$3\frac{5}{8}$	1030	16·44
$1\frac{15}{16}$	402	6·44	$3\frac{11}{16}$	1056	16·84
2	421	6·74	$3\frac{3}{4}$	1083	17·35
$2\frac{1}{16}$	442	7·08	$3\frac{13}{16}$	1112	17·82
$2\frac{1}{8}$	462	7·40	$3\frac{7}{8}$	1139	18·25
$2\frac{3}{16}$	483	7·74	$3\frac{15}{16}$	1166	18·68
$2\frac{1}{4}$	503	8·06	4	1193	19·11
$2\frac{5}{16}$	525	8·41	$4\frac{1}{16}$	1221	19·56
$2\frac{3}{8}$	547	8·76	$4\frac{1}{8}$	1250	20·01
$2\frac{7}{16}$	568	9·10	$4\frac{3}{16}$	1279	20·49
$2\frac{1}{2}$	589	9·43	$4\frac{1}{4}$	1306	20·93
$2\frac{9}{16}$	612	9·80	$4\frac{5}{16}$	1336	21·41
$2\frac{5}{8}$	634	10·16	$4\frac{3}{8}$	1365	21·87
$2\frac{11}{16}$	657	10·36	$4\frac{7}{16}$	1394	22·34
$2\frac{3}{4}$	680	10·89	$4\frac{1}{2}$	1424	22·82
$2\frac{13}{16}$	704	11·28	$4\frac{9}{16}$	1454	23·30
$2\frac{7}{8}$	727	11·65	$4\frac{5}{8}$	1483	23·76
$2\frac{15}{16}$	751	12·05	$4\frac{11}{16}$	1514	24·26
3	775	12·41	$4\frac{3}{4}$	1544	24·74
$3\frac{1}{16}$	800	12·82	$4\frac{13}{16}$	1575	25·24
$3\frac{1}{8}$	825	13·22	$4\frac{7}{8}$	1605	25·72
$3\frac{3}{16}$	850	13·62	$4\frac{15}{16}$	1635	26·22

Messrs. Donkin and Salter made more recent measurements of the flow of water over a bay of rectangular form, $1\frac{1}{2}$ inches wide, cut square out of sheet brass $\frac{1}{16}$ inch thick. They give the general formula for theoretical discharge, reduced for pounds and inches, as follows:—

$$Q = L\ 40 \cdot 082 \sqrt{h^3} \qquad . \quad . \quad . \quad . \qquad (4)$$

L = length of bay, in inches.
h = head, or height over bay, in inches.
Q = pounds of water discharged, per minute.

The co-efficients of actual discharge vary from 64 to 62 per cent. of the theoretical discharge, for heads of from ½ inch to 3 inches.

Flow of Water through a Submerged Weir.

A horizontal rectangular opening, 6 inches deep, 6 feet wide, was made in a board 5 inches thick, the upper and lower surfaces being rounded to a semicircular section, 2½ inches radius. The opening was entirely submerged at the inner side, under heads of from 6 inches to 4 feet. The efficiency of discharge varied from 73 per cent. to 78 per cent.

Water Power.

The power of a fall of water for work, is measured by the product of the weight of water falling in a given time, by the height of the fall. The fall is measured from the surface of the head-water to the surface of the tail-water when the mill is at work. In calculations of water power, the weight of a cubic foot of water is commonly taken at 62½ pounds.

The potential horse-power of a stream is measured in the same way in terms of the fall or difference of level of the upper and lower gauge points.

The proportion of the horse-power of the fall that can be utilised depends upon the efficiency of the motor.

Water-Wheels.

Under-shot wheels, having radial floats, are from 10 feet to 25 feet in diameter, and have an efficiency of from 27 per cent. to 30 per cent.

Poncelet's under-shot wheels have curved floats. The efficiency is about 65 per cent. for falls of 4 feet or less; and from 55 per cent. to 50 per cent. for falls of from 6 feet to 6½ feet. The velocity of the floats should be 55 per cent. of that of the water.

Breast wheels have an efficiency of 70 per cent. when the height of the fall is about 8 feet; 50 per cent. for 4 feet of fall. The most suitable velocity of the floats is 4¼ feet per second. The diameter should be at least 11½ feet; it is seldom more than double this.

Over-shot wheels are employed for heads of from 13 feet to 20 feet. The velocity of the floats should be at least 3 feet per second: say 6½ feet for the smaller diameters; 10 feet for the larger diameters. The efficiency is from 70 per cent. to 75 per cent.

Whitelaw's water-mill—a development of Barker's mill—has been proved experimentally to show 76 per cent. of efficiency. In ordinary, the efficiency is about 55 per cent.

The Fourneyson turbine, having an outward flow, has an efficiency of from 60 per cent. to 70 per cent. The Jonval turbine, having a downward flow, has usually 72 per cent. efficiency, under a full charge. It varies from 68 per cent. to 80 per cent. The vortex wheel, or inward-flow turbine, designed by Mr. James Thomson, has realised an efficiency of 77½ per cent. The Swain turbine, in which an inward and a downward discharge are combined, when tested by Mr. J. B. Francis, realised a maximum efficiency of 84 per cent. At half gate the maximum efficiency was 78 per cent.

The Girard turbine, or tangential wheel, has yielded an efficiency of 87 per cent.; at moderate speeds, in ordinary practice, from 75 per cent. to 80 per cent.

Hydraulic Power.

The Armstrong hydraulic machines work with efficiency varying with the multiplying gear, as follows:—

	Efficiency per cent.		Efficiency per cent.
Direct-acting	93	10 to 1	63
2 to 1	80	12 to 1	59
4 to 1	76	14 to 1	54
6 to 1	72	16 to 1	50
8 to 1	67		

Conditions:—Ordinary pump packing, with sheaves and wrought-iron pins. With special precautions, comprising large sheaves, and small hard pins, the efficiency of a machine multiplying 20 to 1 was as high as 66 per cent. With the accumulator rising or falling, at 700 lbs. pressure per square inch, the friction of the ram is about 2¼ per cent.

The loss by friction in a steam-engine pumping into an accumulator, has been taken at 8·3 per cent. The ultimate efficiency is given by compounding the engine efficiency with the efficiency of the machine.

The ram of the hydraulic press is packed with a leat collar, the friction of which is,—

1 per cent. of the pressure for a 4-inch ram.
½ ,, ,, ,, ,, 8 ,,
¼ ,, ,, ,, ,, 16 ,,

Hydraulic Transmission of Motive Power.

At the Central Pumping Station, Falcon Wharf, Blackfriar of the London Hydraulic Power Company, there are tw accumulators having 20-inch rams of 23-feet stroke, loaded fo a pressure of 750 lbs. per square inch. At the Philip La Pumping Station, the accumulator is 13 feet above those, an is loaded to 710 lbs. per square inch. The delivery of powe water from Falcon Wharf is through four 6-inch mains; and at 200 yards distance, through five 6-inch mains. The deliver is 1040 gallons per minute, at a velocity averaging 2·83 fee per second, or 170 feet per minute. The loss of head due to this velocity is 22·896 feet per 1000 yards, by the formula:-

$$\frac{(\text{Gallons per minute})^2 \times \text{length of pipe in yards}}{(3 \times \text{diameter of pipe in inches})^5}$$

The most distant point of the main is 5320 yards, or jus over 3 miles, from the accumulators. In a circuit of 5 miles the normal difference of pressure, or loss of head, was 20 fee head. To allow for such losses, as well as for valve passage and bends, the stated pressure supplied is 700 lbs. per square inch. At the end of 1887, the total length of mains laid wa nearly 27 miles. There were then about 600 machines working from the mains in London, when the largest quantity of power delivered in one week was a little over 2,000,000 gallons, or 3,333 gallons per machine. The maximum consumption in any one hour was 35,000 gallons; the minimum, 1500 gallons. The practical efficiency—brake horse-power of hydraulic motors—may be fixed, says Mr. E. B. Ellington, the engineer of the company, at from 50 to 60 per cent. of the indicator power developed at the central station.

By the results of special trials, when 178½ indicator horse-power was developed, 4558 gallons of water were pumped per cwt. of coal consumed, with the Vicars stoker; 2·19 pounds of rough small coal being consumed per indicator horse-power per hour. In a trial for one week, under ordinary conditions, 3399 gallons of water were pumped per cwt. of coal consumed.

TABLE 331.—SPEEDS OF CUTTING TOOLS. (J. Roze.)

Work Diameter. Inches.	Roughing Cuts. Feet per Minute.	Roughing Cuts. Lathe Revolutions per Minute.	Feed or Lathe Revolutions per Inch of Tool Travel.	Finishing Cuts. Lathe Revolutions per Minute.	Finishing Cuts. Lathe Revolutions per Inch Tool Travel.
		WROUGHT IRON.			
½	40	305	30	305	60
1	35	133	30	133	60
1½	30	76	30	76	60
2	28	53	25	53	60
2½	28	42	25	42	50
3	28	35	25	35	50
3½	26	28	25	30	50
4	26	24	20	26	50
5	25	18	20	21	50
6	25	15	20	16	50
		CAST IRON.			
1	45	163	30	163	40
1½	45	135	25	135	30
2	40	76	25	76	25
2½	40	61	20	61	20
3	35	44	20	50	16
3½	35	38	18	43	16
4	35	33	18	38	16
4½	30	25	16	28	14
5	30	22	16	26	14
5½	30	20	14	24	12
6	30	19	14	22	12
		BRASS.			
½	120	910	25	910	40
¾	110	556	25	556	40
1	100	382	25	382	40
1¼	90	275	25	275	40
1½	80	203	25	203	40
1¾	80	174	25	174	40
2	75	143	25	143	40
2½	75	114	25	114	40
3	70	89	25	89	40
3½	70	76	25	76	40
4	70	66	25	66	40
4½	65	55	25	55	40
5	65	50	25	50	40
5½	65	45	25	45	40
6	65	41	25	41	40
		TOOL STEEL.			
⅜	24	245	60	245	60
½	24	184	60	184	60
⅝	24	147	50	147	60
¾	24	122	40	122	60
⅞	20	87	30	87	60
1	20	76	30	76	60
1¼	20	61	25	61	50
1½	18	45	25	45	50
2	18	34	25	34	50
2½	18	27	25	27	50
3	18	22	25	22	40
3½	18	19	25	19	40
4	18	17	25	17	40
4½	18	15	25	15	40

Speed of Cutting Tools.

For cast-iron, 150 to 190 inches per minute; boring, 80 inches per minute.

For wrought-iron, 260 to 280 inches per minute.

For yellow brass, 300 inches per minute.

Wood-Working Machinery.

	Feet per Minute.
Teeth of circular saws	9,000
Cutter blocks for planing and moulding (cutting edge)	6,000
Irregular moulding and shaping machines (ditto)	5,000
Band-saw for cutting metals	250
Band-saw blades	4,000
Saw and cutter sharpening machine	5,000
Shafting	250 revolutions.

COLOURS.

TABLE 332.—COLOURS USED IN MECHANICAL AND ARCHITECTURAL DRAWING, TO REPRESENT VARIOUS MATERIALS.

Materials.	Colours used.
Brass	Gamboge.
Brickwork (in section)	Crimson lake.
Brickwork (in elevation)	Crimson lake, mixed with burnt sienna.
Cement	Sepia.
Concrete	Sepia, mottled, with burnt umber.
Copper	Crimson lake, mixed with gamboge.
Glass	Cobalt (blue), mottled.
Iron (wrought)	Prussian blue.
Iron (cast)	Payne's grey.
Lead	Indigo, or light Indian ink.
Leather	Vandyke brown.
Plaster	Sepia.
Slate	Indigo, mixed with crimson lake.
Steel	Crimson lake, mixed with Prussian blue.
Stone	Burnt umber.
Tiles	Indian red.
Wood	Burnt sienna.

ELECTRICAL ENGINEERING.

Electrical Units.

Unit.	Name.	Derivation.	Dimensions in C. G. S.* Units.
Electromotive Force	Volt	Ampère × Ohm	10^{8}
Resistance	Ohm	Volt ÷ Ampère	10^{9}
,,	Megohm	1 million Ohms	10^{15}
Current	Ampère	Volt ÷ Ohm	10^{-1}
,,	Milliampère	1 thousandth Ampère	10^{-4}
Quantity	Coulomb	Ampère × Second	10^{-1}
Capacity	Farad	Coulomb ÷ Volt	10^{-9}
,,	Microfarad	1 millionth Farad	10^{-15}

* C. G. S. = Centimètre-Gramme-Second.

For electric light and power purposes the Ampère is the practical unit of current.

For telegraph purposes the Milliampère is the practical unit of current.

The B.A. (British Association) Ohm, the unit of resistance in general use = resistance of column of pure mercury 1·0482 mètres long, 1 sq. mm. section at 0° C.; it is less in value than the true Ohm, which according to most recent determinations is $\frac{1\cdot0627}{1\cdot0482}$ of the B.A. Ohm.

The Siemens Mercury Unit = ·9540 B.A. Unit.

Insulation resistances are usually measured in Megohms.

When a current of 1 Ampère flows, electricity is passing at the rate of 1 Coulomb per second.

A capacity of 1 Farad charged to a potential of 1 Volt contains 1 Coulomb of electricity.

The Microfarad is the practical unit of capacity ; it is the capacity of about $\frac{1}{3}$rd of a mile of submarine cable.

A Daniell Cell has roughly an Electromotive Force of 1·07 Volts.

Electro-Mechanical Units.

Rate at which work is being done or energy expended in a resistance, R, through which a current, C, is flowing, there being an electromotive force or potential difference, E, between the ends of the resistance is

$$EC,\ C^2 R, \text{ or } \frac{E^2}{R}, \text{ Watts.}$$

1 Watt = $\frac{1}{746}$th of a horse-power, *i.e.*, 1 horse-power = 746 Watts.

1 Kilowatt = 1000 Watts = 1·34 horse-power.

1 Watt = 1 Joule per sec.

A current of 1 Ampère flowing through a resistance of 1 Ohm for 1 sec. does 1 Joule of work.

1 Joule will raise ·238 grammes of water 1° C. in temperature.

1 Calorie is the amount of heat required to raise 1 gramme of water 1° C.

1 Joule = ·238 calories.

1 Joule = ·7373 foot-lbs. = 10,000,000 Ergs.

1 Erg (the absolute unit of *work*) = 1 Centimètre-dyne.

1 Dyne (the absolute unit of *force*) is that force which, acting for 1 sec. on a weight of 1 gramme on a smooth horizontal plane, will give it a velocity of 1 centimètre per sec.

Board of Trade unit = 1000 Watt-hours = work done by 1·34 horse-power during 1 hour.

Measurement of Resistances.

For general purposes, the measurement of resistances is most conveniently effected by the Post Office pattern of Wheatstone bridge, the plan of connections of which is shown in Fig. 81.

Wheatstone Bridge.

Post Office Pattern.

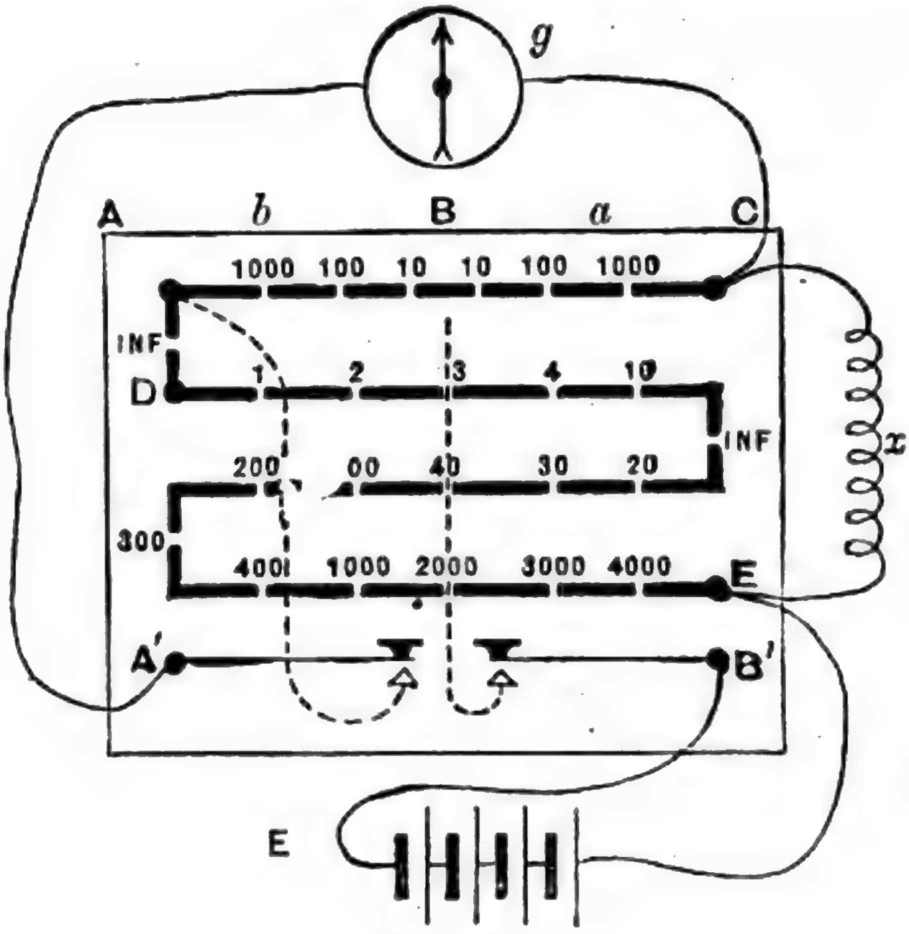

FIG. 81.

x is the resistance to be measured, g a galvanometer of about 1000 ohms resistance, and E a battery (which for ordinary purposes may be about 10 Leclanché cells). In making a measurement plugs must be removed from a and b, and the right hand key pressed and kept down, then the left hand key must be alternately depressed and raised, plugs being removed from between D and E until no movement of the galvanometer needle is observed to take place on the depression and raising of the key. When balance is thus obtained

$$x = \frac{a}{b} r$$

r being the resistance unplugged between D and E (the greatest value of this resistance is 10,000 ohms). By making a greater than b resistances greater than the whole of the resistance between D and E, *i.e.*, 10,000 ohms, can be measured, the greatest value being 1,000,000 ohms, which is obtained by making $a = 1000$ and $b = 10$, for when $r = 10{,}000$ ohms, then

$$x = \frac{1000}{10} \times 10{,}000 = 1{,}000{,}000 \text{ ohms.}$$

By making a less than b resistances less than 1 ohm can be measured, the least value being ·01 ohm, which is obtained by making $a = 10$ and $b = 1000$, for when $r = 1$ ohm, then

$$x = \frac{10}{1000} \times 1 = {\cdot}01 \text{ ohms.}$$

Individual Resistance of 3 or more Telegraph Wires.

In order to avoid errors due to earth currents or an imperfect earth when measuring the conductor resistance of 3 or more telegraph wires,

Loop wires 1 and 2 and let measured resistance be r_1
„ „ 1 „ 3 „ „ „ r_2
„ „ 2 „ 3 „ „ „ r_3

then

Resistance of No. 1 Wire $= \frac{r_1 + r_2 - r_3}{2}$
„ „ 2 „ $= r_1 -$ Resistance of No. 1 Wire
„ „ 3 „ $= r_3 -$ „ „ 2 „

As the resistance of No. 1 wire is thus known we can loop it with any number of other wires, and having ascertained the resistances of the loops, the resistance of any one of the wires is given by subtracting the resistance of No. 1 wire from the resistance of the loop.

Measurement of Low Resistances.

For measuring low resistances—*i.e.* resistances of less than 1 ohm—with accuracy, the measurements are usually made by means of the "Metre" bridge :—

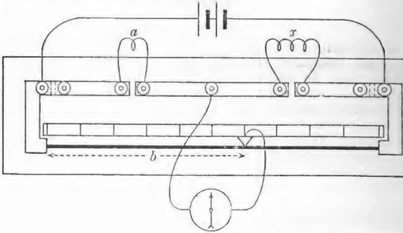

FIG. 82.

a is a standard resistance of 1 ohm, x is the low resistance to be measured. A slider connected to one end of the galvanometer is moved until no movement of the needle takes place on depressing the slider contact, then

$$x = \frac{1000}{b} - 1$$

The galvanometer should have a resistance of about $\frac{1}{10}$th ohm, and the battery should be about 2 large size Leclanché cells. Great care should be taken that all the connections to the terminals are well made, and that the surfaces in contact are scraped bright.

Measurement of High Resistances.

For measuring high resistances, *i.e.* resistances exceeding 1 megohm, such as the *Insulation resistance* of a well insulated wire, the bridge method cannot be adopted with accuracy; in these cases the "deflection" method must be used, and a galvanometer of high resistance and one in which the deflections are directly proportional to the current, be employed. The galvanometer most suitable for the purpose is the "Thomson Reflecting."

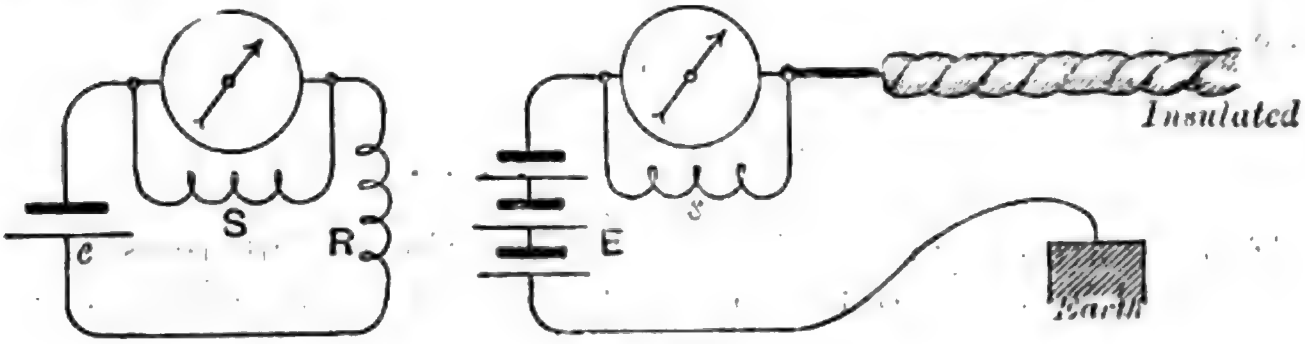

Fig. 83.

A small battery *e* (usually 1 cell) is first connected up with the galvanometer and with a resistance R of 10,000 ohms (the resistance between D and E of the Post Office Wheatstone bridge may be used for the purpose), the galvanometer being shunted by a shunt S (usually the $\frac{1}{1000}$th shunt) so that a convenient deflection D is obtained; this is called taking the *constant*. The connections are then altered as shown by the second fig., a large battery E (about 100 or more cells) being used, and the wire whose insulation is to be measured being joined up as shown. Let the deflection be *d*, and the shunt, *s*, on the galvanometer be the $\frac{1}{n}$th (usually $\frac{1}{10}$th, $\frac{1}{100}$th or $\frac{1}{1000}$th, *i.e.* $n = 10$, 100, or 1000); also let the shunt used when the *constant* is taken be the $\frac{1}{N}$th shunt, then

$$\text{Insulation resistance of wire} = \frac{D \times N}{n} \times K \div d$$

where K is the ratio between the number of cells used in taking D and in taking the constant; thus if *d* is given by 100 cells and D by 1 cell, then $K = 100$. When great accuracy is required, the exact ratio of the force of the large to the small battery has to be determined, for it is seldom that 100 cells have exactly 100 times the force of 1 cell, though in a large number of cases it is sufficient to consider it as such, care being taken that the cells are all in good condition. If a *megohm* resistance (1,000,000 ohms) is available, the *constant* may be taken with the same battery as is used for testing the insulated wire, the megohm being used in the place of the 10,000 ohms; in this case $K = 1$.

Care should be taken that the ends of the insulated wire being tested are well trimmed and quite dry; preferably the ends should be painted over with, or dipped for a moment in, hot paraffin *wax*, *not* paraffin *oil*.

Combined Resistances.

The joint resistance of any number of resistances joined in parallel or multiple arc, is equal to the reciprocal of the sum of the reciprocals of their respective resistances; thus the joint resistance in parallel of wires whose resistances are r_1, r_2, r_3, r_4, &c., is

$$\frac{1}{\frac{1}{r_1}+\frac{1}{r_2}+\frac{1}{r_3}+\frac{1}{r_4}+\ \ldots\ldots}$$

If there are only *two* resistances, then their joint resistance in parallel is equal to the product of their values divided by their sum, or

$$\frac{r_1 r_2}{r_1+r_2}$$

Shunts.

If C=total current flowing through a galvanometer of resistance G shunted by a resistance S, and c the portion of this current flowing through the galvanometer, then

$$C=c\frac{G+S}{S}.$$

$\frac{G+S}{S}$ is called the *multiplying power* of the shunt.

The joint resistance of the galvanometer and shunt is

$$\frac{GS}{G+S}.$$

The shunt required to give a certain multiplying power n is

$$\frac{G}{n-1}.$$

The joint resistance of the shunt and galvanometer in this case is

$$\frac{G}{n}.$$

If it is required to make up for the reduction of resistance in the circuit caused by the addition of the shunt, a *compensating* resistance,

$$\frac{G^2}{G+S}, \text{ or } G\frac{n-1}{n},$$

must be added in the circuit.

Ratio of Current to Resistance and Potential Difference.

C = current flowing through a wire,
V = potential difference between its ends,
R = resistance of wire,

$$C=\frac{V}{R},\ R=\frac{V}{C},\ V=C\ R.$$

Corrections for Temperature.

For general Telegraphic and Electric Light purposes, the resistances of copper conductors are reduced or corrected from the measured results at the observed temperature to the values at 60° F., this being the normal temperature of the air; this reduction can be effected by the following table:—

TABLE 333.—MULTIPLYING COEFFICIENTS FOR REDUCING THE OBSERVED RESISTANCE OF ORDINARY COPPER WIRE AT ANY TEMPERATURE TO 60° F.

Temp. F.	Coeff.	Temp. ° F.	Coeff.	Temp. ° F.	Coeff.	Temp. ° F.	Coeff.	Temp. ° F.	Coeff.
90	·9392	79	·9610	68	·9834	57	1·006	46·5	1·029
89·5	·9402	78·5	·9621	67·5	·9844	56·5	1·007	46	1·030
89	·9412	78	·9631	67	·9855	56	1·008	45·5	1·031
88·5	·9421	77·5	·9641	66·5	·9865	55·5	1·009	45	1·032
88	·9431	77	·9651	66	·9875	55	1·010	44·5	1·033
87·5	·9441	76·5	·9661	65·5	·9886	54·5	1·012	44	1·034
87	·9451	76	·9671	65	·9896	54	1·013	43·5	1·035
86·5	·9461	75·5	·9681	64·5	·9906	53·5	1·014	43	1·036
86	·9471	75	·9691	64	·9917	53	1·015	42·5	1·037
85·5	·9481	74·5	·9701	63·5	·9927	52·5	1·016	42	1·038
85	·9491	74	·9711	63	·9937	52	1·017	41·5	1·039
84·5	·9501	73·5	·9722	62·5	·9948	51·5	1·018	41	1·041
84	·9510	73	·9732	62	·9958	51	1·019	40·5	1·042
83·5	·9520	72·5	·9742	61·5	·9969	50·5	1·020	40	1·043
83	·9530	72	·9752	61	·9979	50	1·021	39·5	1·044
82·5	·9540	71·5	·9762	60·5	·9990	49·5	1·022	39	1·045
82	·9550	71	·9772	**60**	1·000	49	1·023	38·5	1·046
81·5	·9560	70·5	·9783	59·5	1·001	48·5	1·024	38	1·047
81	·9570	70	·9793	59	1·002	48	1·025	37·5	1·048
80·5	·9580	69·5	·9803	58·5	1·003	47·5	1·026	37	1·049
80	·9590	69	·9814	58	1·004	47	1·027	36·5	1·050
79·5	·9600	68·5	·9824	57·5	1·005				

Example.—The resistance of a copper wire at 48° F. is 200 ohms; what is its resistance at 60° F.?

Resistance at 60° F. = 200 × 1·025 = 205·0 ohms.

For Submarine Cable tests the results are reduced to 75° F. by the following table:—

TABLE 334.—MULTIPLYING COEFFICIENTS (k) FOR REDUCING THE OBSERVED RESISTANCE OF ORDINARY COPPER WIRE AT ANY TEMPERATURE TO 75° F.

Temp. ° F.	Coeff.	Temp. ° F.	Coeff.	Temp. ° F.	Coeff.	Temp. ° F.	Coeff.	Temp. ° F.	Coeff.
90	·9691	79	·9917	68	1·015	57	1·038	46·5	1·061
89·5	·9701	78·5	·9927	67·5	1·016	56·5	1·039	46	1·062
89	·9711	78	·9937	67	1·017	56	1·041	45·5	1·064
88·5	·9722	77·5	·9948	66·5	1·018	55·5	1·042	45	1·065
88	·9732	77	·9958	66	1·019	55	1·043	44·5	1·066
87·5	·9742	76·5	·9969	65·5	1·020	54·5	1·044	44	1·067
87	·9752	76	·9979	65	1·021	54	1·045	43·5	1·068
86·5	·9762	75·5	·9990	64·5	1·022	53·5	1·046	43	1·069
86	·9772	**75**	1·000	64	1·023	53	1·047	42·5	1·070
85·5	·9783	74·5	1·001	63·5	1·024	52·5	1·048	42	1·071
85	·9793	74	1·002	63	1·025	52	1·049	41·5	1·072
84·5	·9803	73·5	1·003	62·5	1·026	51·5	1·050	41	1·074
84	·9814	73	1·004	62	1·027	51	1·051	40·5	1·075
83·5	·9824	72·5	1·005	61·5	1·029	50·5	1·053	40	1·076
83	·9834	72	1·006	61	1·030	50	1·054	39·5	1·077
82·5	·9844	71·5	1·007	60·5	1·031	49·5	1·055	39	1·078
82	·9855	71	1·008	60	1·032	49	1·056	38·5	1·079
81·5	·9865	70·5	1·009	59·5	1·033	48·5	1·057	38	1·080
81	·9875	70	1·010	59	1·034	48	1·058	37·5	1·082
80·5	·9886	69·5	1·012	58·5	1·035	47·5	1·059	37	1·083
80	·9896	69	1·013	58	1·036	47	1·060	36·5	1·084
79·5	·9906	68·5	1·014	57·5	1·037				

Example.—The resistance of a copper wire at 57° F. is 300 ohms; what is its resistance at 75° F.?

Resistance at 75° F. = 300 × 1·038 = 311·4 ohms.

By means of the foregoing Table the temperature of the Sea in which a Submarine Cable is laid can be determined. provided the resistance of the conductor of the Cable at 75° was ascertained during the course of manufacture. The measured resistance of the Cable when the latter is laid, divided into the resistance at 75° gives a coefficient which in the above Table corresponds to the temperature of the conductor. that is of the Sea.

The reduction to 75° of the Insulation (dielectric) tests is effected by the following table:—

TABLE 335.—DIVIDING COEFFICIENTS FOR CORRECTING THE OBSERVED RESISTANCE OF GUTTA-PERCHA AT ANY TEMPERATURE TO 75° F

Temp. ° F.	Coeff.	Temp. ° F.	Coeff.	Temp. ° F.	Coeff.	Temp. ° F.	Coeff.	Temp. ° F.	Coeff.
90	·3197	80	·6837	70	1·463	60	3·128	50	6·692
89·5	·3320	79·5	·7102	69·5	1·519	59·5	3·250	49·5	6·951
89	·3449	79	·7378	69	1·578	59	3·376	49	7·220
88·5	·3583	78·5	·7663	68·5	1·639	58·5	3·506	48·5	7·500
88	·3722	78	·7960	68	1·703	58	3·642	48	7·791
87·5	·3866	77·5	·8269	67·5	1·769	57·5	3·783	47·5	8·093
87	·4016	77	·8589	67	1·837	57	3·930	47	8·406
86·5	·4171	76·5	·8922	66·5	1·908	56·5	4·082	46·5	8·732
86	·4343	76	·9267	66	1·982	56	4·240	46	9·070
85·5	·4501	75·5	·9627	65·5	2·059	55·5	4·405	45·5	9·422
85	·4675	**75**	1·000	65	2·139	55	4·575	45	9·787
84·5	·4856	74·5	1·039	64·5	2·222	54·5	4·753	44·5	10·17
84	·5044	74	1·079	64	2·308	54	4·937	44	10·56
83·5	·5240	73·5	1·121	63·5	2·397	53·5	5·128	43·5	10·97
83	·5443	73	1·164	63	2·490	53	5·327	43	11·39
82·5	·5654	72·5	1·209	62·5	2·587	52·5	5·533	42·5	11·84
82	·5873	72	1·256	62	2·687	52	5·748	42	12·29
81·5	·6100	71·5	1·305	61·5	2·792	51·5	5·970	41·5	12·77
81	·6337	71	1·355	61	2·899	51	6·202	41	13·27
80·5	·6582	70·5	1·408	60·5	3·012	50·5	6·442	40·5	13·78

Example.—The insulation resistance at 62° F. of a wire insulated with gutta-percha is 500 megohms; what is the resistance at 75° F.?

Resistance $= 500 \div 2{\cdot}687 = 186{\cdot}1$ megohms.

Fault Testing.

Blavier's Method.

Insulate further end of line and measure resistance l.

Put further end of line to earth, and measure resistance l_1.

Resistance of line when good $=$ L.

Resistance up to fault $= l_1 - \sqrt{(l - l_1)(L - l_1)}$.

Overlap Method.

Measure resistance l from station A, station B insulating.

Measure resistance l_2 from station B, station A insulating.

Resistance of line when good = L.

Resistance up to fault from station A $= \frac{L + l - l_2}{2}.$

Murray's Loop Method.

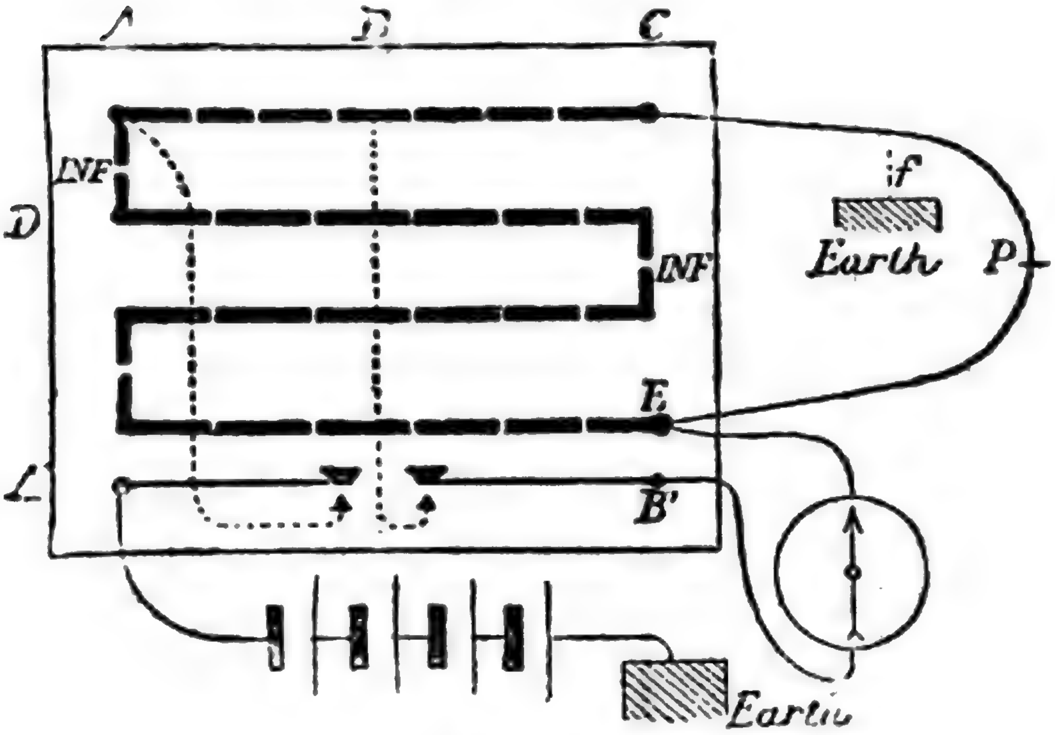

FIG. 84.

C P faulty line. E P good line.

All plugs to be inserted between B and C, also plug between A and D.

10, 100, or 1000 plugs (according to length of loop) to be taken out between A and C.

Left-hand key to be held permanently down, and *right*-hand key to be manipulated.

D E to be adjusted till equilibrium is produced.

Resistance from C up to fault $= L \frac{b}{b+d}.$

L = total resistance of entire loop (measured by bridge, page 599).

b = resistance unplugged in A B.

d = " " " D E.

Varley's Loop Method.

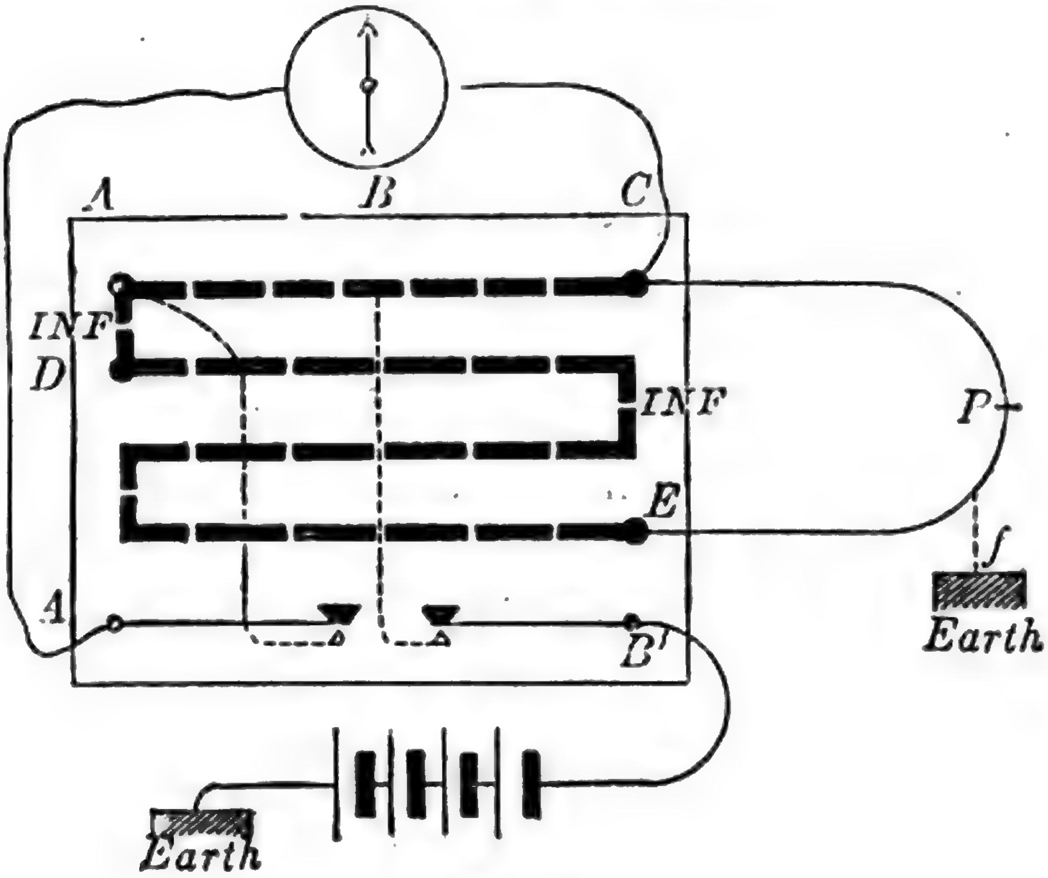

FIG. 85.

E P. faulty line. C P good line.

10, 100, or 1000 plugs (according to length of loop) to be taken out between A and B and between B and C.

Right-hand key to be held permanently down, and *left*-hand key to be manipulated.

D E to be adjusted till equilibrium is produced.

Resistance from E up to fault $= \dfrac{bL - ad}{b + a}$.

L = total resistance of entire loop (measured by bridge, page 599).

$a =$ resistance unplugged in B C.

$b =$,, ,, ,, A B.

$d =$,, ,, ,, D E.

Inductive or Electrostatic Capacity.

Inductive capacities are measured by comparing the discharge from a standard condenser with the discharge from the insulated wire whose capacity is required; the capacities will be in direct proportion to the discharges if the latter are measured on a Thomson reflecting galvanometer.

Inductive capacity of a wire insulated with gutta-percha

$$= \frac{\cdot 170}{\log.\ \frac{D}{d}} \text{ m. farads per knot, approximately.}$$

$$= \frac{\cdot 147}{\log.\ \frac{D}{d}} \quad \text{,,} \quad \text{,, statute mile ,,}$$

where D = diameter of insulating material,

d = ,, conductor.

For india-rubber the values are about 10 to 15 per cent. less.

Specific inductive capacity of the material with which wire is insulated, *i.e.*, the capacity of a cube knot,

$$= K \frac{\log.\ \frac{D}{d}}{2\cdot 728}$$

where K = capacity in microfarads per knot of the insulated wire.

Inductive capacity of an aerial line

$$= \frac{\cdot 061637}{\log.\ \frac{4h}{d}} \text{ m. farads per statute mile, approx.}$$

where d = diameter of wire in mils.

h = height of wire above ground, also in mils.

Electro-Chemistry.

One ampère of current decomposes ·00009324 gramme water per second, liberating ·000010384 gramme of hydroge and ·00008286 gramme of oxygen.

C ampères of current in T seconds will throw down or dep sit from a solution of any salt of a metal

CTa grammes, or CTb grains,

where a and b are the values given in the following Table:–

TABLE 336.—VALUES OF *a* AND *b*, ELECTRO-CHEMICAL DEPOSITS.

Metal.	*a* (grammes).	*b* (grains).
Hydrogen	·000010384	·00016025
Aluminium	·00009449	·0014582
Magnesium	·00012430	·0019182
Iron (Ferric)	·00019356	·0029869
„ (*Ferrous*)	*·00029035*	*·0044808*
Sodium	·00023873	·0036842
Nickel	·00030425	·0046953
Tin (Stannic)	·00030581	·0047085
„ (*Stannous*)	*·00061162*	*·0094387*
Copper (Cupric)	·00032709	·0050478
„ (*Cuprous*)	*·00065419*	*·0100960*
Zinc	·00033696	·0052001
Potassium	·00040539	·0062561
Gold	·00067911	·0104800
Mercury (Mercuric)	·00103740	.0160100
„ (*Mercurous*)	*·00207470*	*·0320170*
Lead	·00107160	·0165370
Silver	·00111800	·0172540

Primary Batteries.

A current of 1 ampère for 1 hour in a primary battery will dissolve 1·213 grammes = 18·72 grains of zinc *in each cell*, provided there is no local action.

Quantity of zinc consumed in a primary battery per horse-power-hour

$$=\frac{1·995}{E}\text{lbs.},$$

where E is the electromotive force of the battery.

Quantity of any metal (used as the positive plate) consumed in a primary battery per horse-power-hour

$$=\frac{5921·8\times a}{E}\text{ lbs.},$$

where *a* is the value given in the foregoing table.

Weight for weight primary batteries contain a much greater storage of energy than *Accumulators*, but the energy being produced by the combustion of zinc and the decomposition of acids is more expensive to obtain.

Accumulators.

The largest size accumulators (Electric Power Storage Company) have a capacity of 660 ampère-hours, and weigh, when charged with acid, 265 lbs. The acid (acidulated water). weighs 73 lbs.; the approximate outside dimensions of the glass cells are,—length, 18¼ inches; width, 11¼ inches; height, 13⅜ inches; height over all, 15⅞ inches; each cell contains 31 plates. The cells are charged with a current of from 50 to 60 ampères, and discharged with a current not exceeding 60 ampères. The smaller cells are rather heavier in proportion.

Taking the plates alone, each 1 lb. weight of plates will store about 30,000 foot-pounds of energy.

The acidulated water contains 25 per cent. of sulphuric acid.

The cells should never be left standing uncharged, and should not be discharged to more than ⅔rds of their capacity; they should not be discharged beyond the maximum rate for which they are designed, *i.e.*, a cell which is intended to discharge at a maximum rate of 60 ampères should not be worked at 70 ampères as this would tend to spoil the cells.

About 80 per cent. of the charge can be obtained by discharge if the cells are in good condition.

The electromotive force of accumulators averages 2 volts, though the force is slightly higher when the cells are freshly charged.

The charging electromotive force should not exceed the electromotive force of the accumulator by more than 5 per cent.

If E = the full electromotive force of the charging dynamo and C = the current passing, the *total* rate at which work is being expended on the charging is

$$EC \text{ Watts};$$

a portion of the work is wasted in heating the accumulator.

The actual rate at which work is being accumulated in the accumulator is

$$E' C$$

where E′ is the electromotive force at the accumulator terminals *when the latter are disconnected.*

In the use of accumulators there is first a loss in charging, the loss being due to waste in the dynamo and waste in the accumulator: there is also waste in the accumulator in discharging partly due to heating and partly to local action.

It is more economical to charge accumulators with a weak current continued for a lengthened period than with a strong current for a short period.

The resistance of an accumulator (when discharging) is

$$\frac{E_1 - E_2}{C}$$

where E_1 is the electromotive force on open circuit, and E_2 the electromotive force on closed circuit.

The accumulator cells should be kept in as dry (but not warm) a situation as possible.

For charging accumulators a *shunt* wound dynamo must be used.

Current Induction.

If e = electromotive force set up in a rectilinear conductor of length l moving through a magnetic field of intensity H,
v = velocity of moving conductor,
α = angle the conductor makes with the lines of force,
ϕ = angle between the direction of motion and the direction of the force exerted between the magnetic field and the conductor; then,

$$e = \mathrm{H}\, l\, v \sin \alpha \cos \phi.$$

If the conductor is at right angles to and moves so as to cut the lines of force at right angles (in which case sin α cos ϕ each equal 1), then 1 Gauss is the strength of field in which a length of one million centimetres of wire moving with unit velocity (1 centimetre per sec.), develops 1 volt of electromotive force = 100 times the strength of 1 C. G. S. field.

The strongest field of a dynamo magnet is about 100 Gausses = 100 × 100 = 10,000 C. G. S. units.

1 C. G. S. magnetic field has 1 line of force per square centimetre.

1 Kapp line = 6,000 C. G. S. lines.

1 ,, ,, per square inch = 930 C. G. S. lines per square centimetre.

A magnetic field whose strength is 100 Gausses contains $\frac{10{,}000}{930} = 10{\cdot}75$ Kapp lines per square inch.

The Kapp line was proposed as a suitable factory unit because the revolutions of dynamo armatures are usually reckoned per minute instead of per second (60 secs. = 1 minute), and also by dividing by 100, the units expressing the number of magnetic lines are brought to numerical values easily dealt with and remembered.

DYNAMOS.

The Series Dynamo.

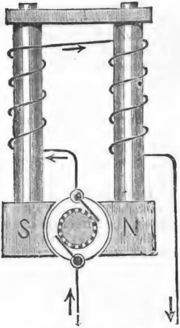

FIG. 86.—Series Wound.

If R = external resistance.
r_a = resistance of armature.
r_m = resistance of field-magnet coils.
E = electromotive force of machine.
e = potential difference between terminals of machine.
c = current strength.

$$e = c\,R = E - (r_a + r_m)\,c$$

Ratio of useful electric energy [illegible] in external circuit to tot[illegible] energy developed $= \frac{R}{R + [illegible] + r_m}$

r_m may with [illegible] be ma[illegible]

Series machi[illegible] for ru[illegible]

The Shunt Dynamo.

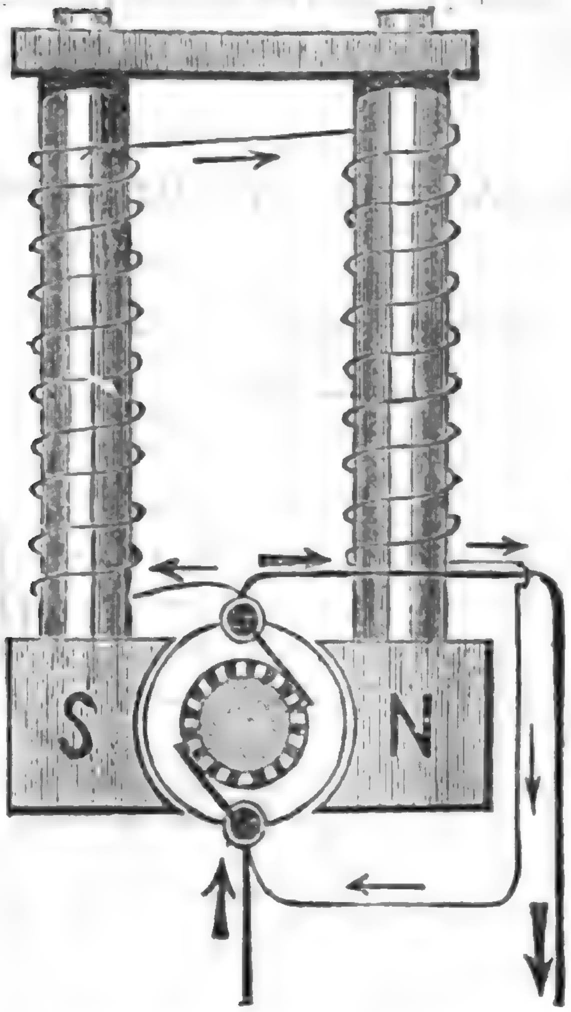

FIG. 87.—Shunt Wound.

If R = external resistance,
r_a = resistance of armature,
r_s = " " field-magnet coils,
E = electromotive force of machine,
e = potential difference between terminals of machine,
c = current in external circuit,
c_a = " " armature,
c_s = " " field-magnet coils,

$$e = c\,\mathrm{R} = c_s\,r_s = \mathrm{E} - r_a\,(c + c_s)$$

$$\mathrm{E} = \left(r_a + \frac{\mathrm{R}\,r_s}{\mathrm{R} + r_s}\right)c_a = e\,r_a\left(\frac{1}{\mathrm{R}} + \frac{1}{r_a} + \frac{1}{r_s}\right)$$

Ratio of useful electric energy available in external circuit to total energy developed $\left.\vphantom{\frac{1}{1}}\right\} = \dfrac{\mathrm{C}^2\,\mathrm{R}}{\mathrm{C}^2\,\mathrm{R} + c_s^2\,r_s + c_a^2\,r_a}$

In order that a shunt dynamo may give in the external circuit as much as 90 per cent. of its total electric energy the resistance of the shunt must be at least 364 times as great as that of the armature.

Practically the armature resistance may be made $\frac{1}{20}$th of the external resistance, and the shunt resistance 20 times as great.

Shunt machines are used for charging accumulators and for electroplating.

Separately Excited Dynamos.

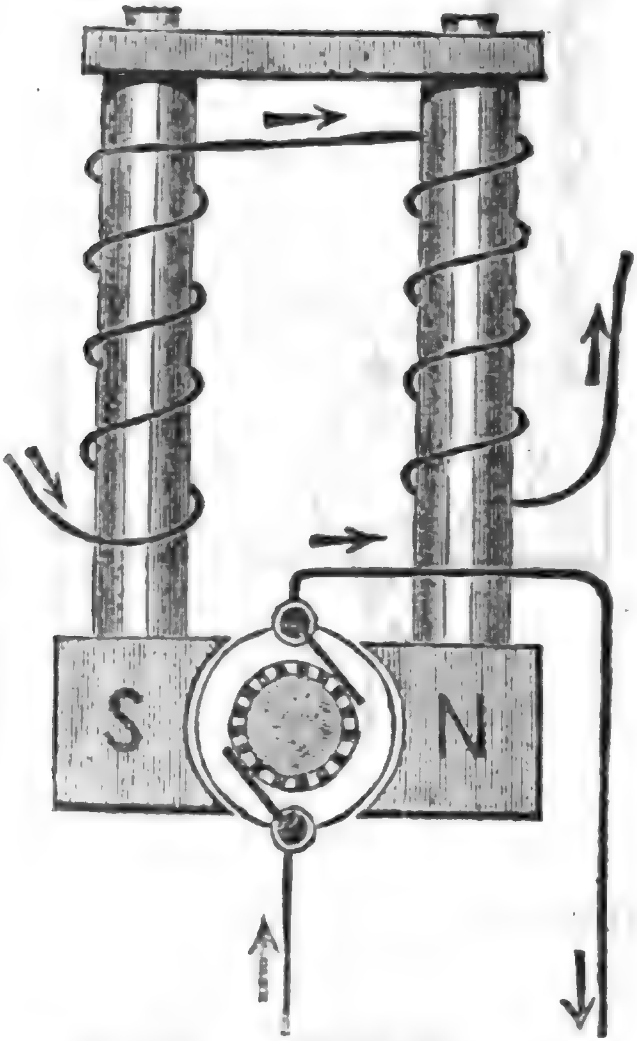

FIG. 88.—Separate Excitation.

If R = external resistance,
r_m = resistance of field-magnet coils,
E = electromotive force of machine,
c = current in external circuit,
c_m = " " field-magnets,

$$E = c\,R$$

$$\left.\begin{array}{l}\text{Ratio of useful electric energy available}\\ \text{in external circuit to total energy}\\ \text{developed}\end{array}\right\} = \frac{C^2 R}{c^2 R + c_m{}^2 r_m}$$

This gives the distribution of the energy as far as the machine itself is concerned, but there is also a loss of energy in the dynamo used for exciting the field magnets which must be taken into account. This exciting dynamo may be used to excite the field magnets of several dynamos.

Compound Wound Dynamos.

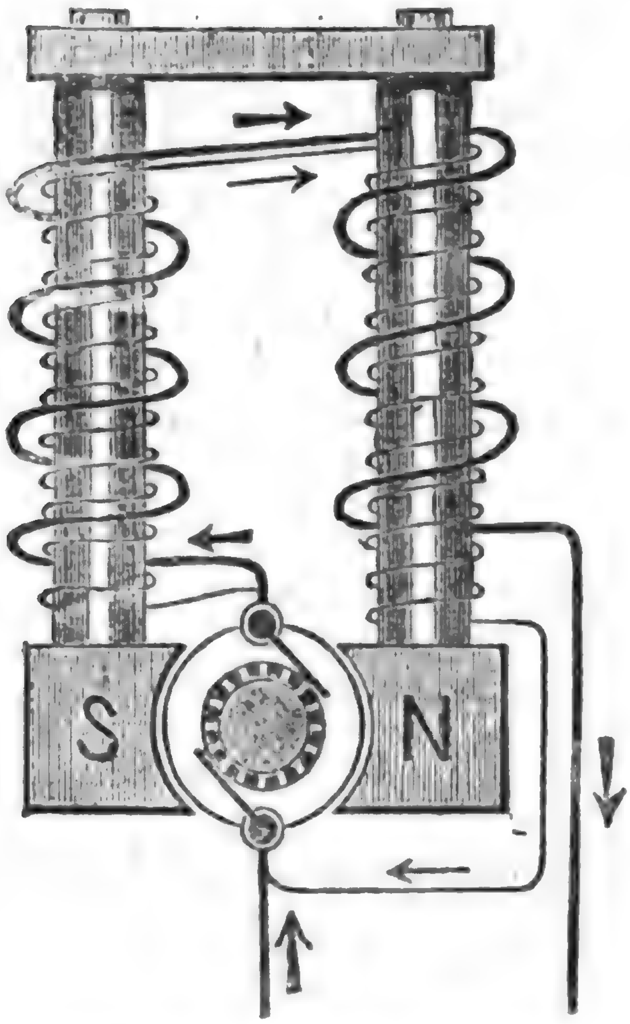

Fig. 89.—Compound Wound.

If R = external resistance.
r_a = resistance of armature.
r_s = ,, ,, field-magnet shunt coils.
r_m = ,, ,, ,, series ,,
c = current in external circuit.
c_a = ,, ,, armature coils.
c_s = ,, ,, shunt ,,
c_m = ,, ,, series ,,

Ratio of useful electric energy available in external circuit to total energy developed $= \dfrac{c^2 R}{c^2 R + c_a^2 r_a + c_s^2 r_s + c_m^2 r_m}$

r_s should be from 1,000 to 1,500 times r_a, and r_m about two-thirds r_a.

Compound machines enable a constant potential to be kept at their terminals irrespective of the work to be done in the external circuit. This is required in the case of an installation of incandescent lamps.

Alternating Current Dynamos.

If E = electromotive force after time t.
C = current ,, ,, ,,
T = half period of a complete alternation.
t = time from the instant at which the electromotive was zero when changing from the direction reckoned as negative to that reckoned as positive.
K = a constant.

$$C = \frac{K}{T} \sin \frac{\pi}{T} t$$

If C_m = mean current during the time T.

$$C_m = \frac{2\,K}{\pi\,T}$$

When an alternating current passes through a wire, L, the resistance due to the self-induction in the wire whose ohmic resistance is R and self-induction L is

$$\frac{1}{T} \sqrt{R^2\,T^2 + \pi^2\,L^2}$$

If C′ be the current indicated on an electro-dynamometer

$$C_m = \frac{9}{10}\,C'$$

Watts consumed in lamps worked with alternating currents $\Bigg\} = \dfrac{r\,T\,\sqrt{A^2\,V^2}}{\sqrt{l^2\,\pi^2 + r^2\,T^2}}$

Where A = mean current measured on an electro-dynamometer.
V = ,, potential at terminal of lamps.
r = ohmic resistance of lamp when hot.
l = coefficient of self-induction.
T = half period of a complete alternation.

Efficiency of Dynamos.

$$\text{Commercial efficiency} = \frac{\text{Electrical energy in external current.}}{\text{Mechanical energy applied at dynamo.}}$$

$$\text{Efficiency of conversion} = \frac{\text{Total electrical energy.}}{\text{Mechanical energy applied at dynamo.}}$$

$$\text{Electrical efficiency} = \frac{\text{Electrical energy in External circuit.}}{\text{Total electrical energy.}}$$

The insulation of the various parts of a dynamo is a point of importance; in particular, measurements should be made of the insulation resistance between the terminals of the machine and its metal bed-plate, and between the segments of the collector and the axle.

In order to determine the efficiency of a dynamo, measurements should be made of the horse-power expended at the pulley (which may be done by means of a Prony brake) and of the energy of the electric currents given out. A good dynamo should have a commercial efficiency of at least 50 per cent.

Transformers or Converters.

Transformers are used for reducing the high potential from a dynamo to a low potential for working the lamps, the electric power being transmitted more economically at a high than a low potential, as conductors of small diameter can be used, whilst the danger of a high potential in the consumers houses is avoided.

The efficiency of a good transformer at full output is about 96 per cent. and at one-third output 90 per cent. The weight of a transformer varies from 15 to 50 lb. per horse-power according to the size and type.

The rate of alternation of the current in a transformer varies from about 50 to 130 complete alternations per second. Each type of transformer has its best rate of alternations to give the highest efficiency; if this rate is exceeded or reduced an abnormal rise of temperature takes place.

Transformers are usually made to transform from a potential of 2,000 volts or 1,000 volts down to 100 or to 50 volts.

Great care must be taken in the construction of transformers to avoid any leakage from the primary to the secondary circuit.

The following gives dimensions, &c., of a Westinghouse transformer:—

Primary current, 1·5 ampères at 1,000 volts.
Secondary ,, 37·5 ,, ,, 40 ,,
Outside dimensions, 20 × 6 × 4 inches.
Weight of primary wire, 5 lb. gauge, 35 mils.
,, ,, secondary ,, 5½ ,, ,, 120 ,,

The secondary wire is divided into 25 sections joined in parallel.

Weight of iron, 50 lbs.

Efficiency, 97·2 per cent. (?).

ELECTRIC LAMPS.

Arc Lamps.

If L = lighting power.
C = current.

$$L \propto 100 \left\{ C + \left(\frac{C}{4}\right)^2 \right\} - 200$$

Arc lamps for a given expenditure of energy give ab 7 times the power of an incandescent lamp.

If l = length of arc in millimetres.
E = electromotive force between the carbons.
C = current flowing.
R = resistance of arc.

$$R = \frac{39}{C} + 1{\cdot}8\,\frac{L}{C}$$

In an arc lamp the top or positive carbon burns ab 1½ inches per hour, and twice as fast as the bottom or nega carbon.

A 1000 c.p. lamp requires carbons about $\frac{9}{16}$ths inch diameter; it is usually run at a potential of 50 volts, an takes about 10 ampères; the power required is about 1 hors Arc lamps are usually run in series.

Incandescence Lamps.

A 16 c.p. incandescent lamp is usually run at a potent of 100 volts, and takes ·5 ampère, *i.e.*, requires a power of little over 3 watts per candle.

1 indicated horse-power will run 8 incandescent lamps o 16 c.p.

Incandescence lamps are usually run in multiple arc.

RULES AND REGULATIONS

Of the Institution of Electrical Engineers for the Preventio of Fire Risks arising from Electric Lighting (1888).

Conductors.

1. They must have a sectional area and conductivity so proportioned to the work they have to do that, if double the current proposed is sent through them, the temperature of such conductors shall not exceed 150° F.

2. The conductors, or their casings, should be placed in sight if possible: and they should always be as accessible as circumstances will permit.

3. Within buildings they should all be insulated; and this rule applies equally to all conductors and parts of fittings which may have to be handled.

4. Whatever insulating material is employed, it should not soften until a temperature of 170° F. has been reached, and in all cases the material must be damp-proof.

5. When leads pass through roofs, floors, walls, or partitions, and where they cross or are liable to touch metallic substances, such as bell wires, iron girders, or pipes, they should be thoroughly protected by suitable additional covering; and where they are liable to abrasion from any cause, or to the depredations of rats or mice, they should be encased in some suitable hard material.

6. In the case of portable fittings with which flexible leads are used, special precautions must be taken.

7. Conductors should be kept as far apart as circumstances will permit, the spacing between them being governed by their potential difference.

8. When conductors are carried in very inflammable structures, precautions should be taken to isolate them therefrom.

9. Conductors which are protected on the outside by lead, or metallic armour of any kind, require the greatest care in fixing, on account of the large conducting surface which would become connected to the core in the event of metallic contact between them.

10. In cases where conductors pass into a building, from one building to another, or from one room to another, precautions should be taken to prevent the possibility of fire or water passing along the course of the conductors.

11. All joints must be mechanically and electrically perfect, to prevent heat being generated at these points. When soldering fluids are used in making joints, the latter should be carefully washed and dried before insulation is applied.

12. Under all circumstances complete metallic circuits must be employed. Gas and water pipes must never form part of the circuit, as their joints are rarely electrically good and therefore become a source of danger.

13. Overhead conductors, whether passing over or attached to buildings, must be insulated at their points of support. Precautions must be taken to obviate all risk of short-circuiting where they are likely to touch a building or other overhead conductors and wires, either by their own falling or by being fallen upon by other conductors.

14. In the case of overhead wires, every main should have a lightning protector at each point where it enters or branches into a building.

15. Metal fastenings for fixing conductors should be avoided;

but, when unavoidable, some additional covering should protect the conductor from mechanical injury at such fixing points.

16. The insulation of a system of distribution should be such that the greatest leakage from any conductor to earth (and in case of parallel working, from one conductor to the other, when all branches are switched on, but the lamps, motors, &c. removed), does not exceed one five-thousandth part of the total current intended for the supply of the said lamps, motors, &c.; the test being made at the usual working electromotive force.

17. It will often be found a great convenience and assistance in the prevention of accidents if the positive lead be coloured differently to the negative, or made otherwise distinguishable.

Switches.

18. Every switch or commutator should be of such construction as to comply with the following condition, namely:—That, when the handle is moved or turned to and from the positions of "on" and "off," it is impossible for it to remain in any intermediate position, or to permit of a permanent arc, or heating.

19. The handles of every switch must be completely insulated from the circuit.

20. The main switches of a building should be placed as near as possible to the point of entrance of the conductors, or to the generators of the current if they are within the building itself. Switches should be provided on both leads.

21. Switch-boards should bear clear instructions for their use by the inexperienced.

Electrical Fittings Generally.

22. Switches, commutators, resistances, bare connections, lamps, &c., must be mounted on incombustible bases. Cut-outs mounted on bases of wood rendered uninflammable are admissible. Vulcanite bases are undesirable in damp situations. The cracking of porcelain and earthenware fittings is a source of danger which can be avoided by precautions in fixing.

Cut-outs.

23. All circuits should be protected with cut-outs; and all leads from the mains, or small conductors from larger ones, must be fitted with cut-outs at their branching points.

24. Where fusible cut-outs are used, the section should be

so situated within its frame that the fused metal cannot fall where it may cause a "short-circuit" or an ignition.

25. For all main conductors a cut-out should be provided for both the "flow" and "return," and the two fusible sections must not be in the same compartment.

26. The flexible leads of portable fittings must in all cases be protected by cut-outs at their fixed points of connection.

Arc Lamps.

27. Arc lamps must always be guarded by lanterns or netted globes, so as to prevent danger from ascending sparks and from falling glass and incandescent pieces of carbon.

28. All parts of the lamps and lanterns which are liable to be handled (except by the persons employed to trim them) should be insulated.

The Dynamo.

29. The armatures and field-magnet coils should be thoroughly insulated. Dynamos should always be fixed in dry places, and they must not be exposed to dust flyings or other industrial waste products carried in suspension in the air. They should not be permitted in the working-rooms of mills, where the liability to such dangers exists, or where any inflammable manufactures are carried on or inflammable materials are stored.

30. Motors should be subject to the same conditions; but when it is necessary to use them in positions such as those above referred to, they must be securely cased in, such cases having a non-combustible lining.

Batteries.

31. Both primary and secondary batteries should be placed and used under the same precautions as prescribed for dynamos; and the room in which they are placed should be well ventilated. The batteries themselves must be well insulated.

Transformers.

32. When these are used to transform either direct or alternating currents of high electro-motive force—that is, from or to an electro-motive force of, say, 200 volts—they, together with their switches and cut-outs, must be placed in a fire- and moisture-proof structure—preferably outside the building f which they are required. No part of such apparatus sho be accessible except to the person in charge of their m tenance.

33. In all cases conductors conveying currents of h

electro-motive force inside buildings must be speciall exceptionally insulated, cased in, and the casing made proof.

34. The positive and negative terminals connected to conductors should not be permitted to be nearer each than 12 inches.

35. Transformers which, under normal conditions d heat above 150° F., should not be permitted to remain in

36. Transformers should be so constructed that unde circumstances whatever should a contact between the pri and secondary coils lead the high E.M.F. into the buildin

Maintenance.

37. The value of frequently testing and inspecting apparatus and circuits cannot be too strongly urged precaution against fire. Records should be kept of all so that any gradual deterioration of the system may detected.

38. Cleanliness of all parts of the apparatus and fitting essential to a good maintenance.

39. No repairs or alterations must be made when the cur is "on."

Three-Wire System.

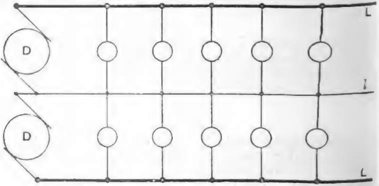

FIG. 90.

In this system of distribution, two equal dynamos, *D*, *D*, joined in series. Three lead-wires are used, two, L, L, bei of larger sectional area than the third, *l*, or centre lead. T advantage of the arrangement is that the main leads can smaller than would be the case if a single dynamo were us and all the lamps were in parallel, whilst by the addition the third or centre wire the breakage of one or more lam does not cause the extinction of the other lamps with whic they are in series, the continuity of the current being kept up by the centre wire.

Electric Motors.

et E = electro-motive force of dynamo.
e = back electro-motive force of motor.
V = potential difference between terminals of dynamo.
V = „ „ „ „ motor.
r_1 = Resistance of dynamo.
r_2 = „ „ motor.
R = „ „ line.
W_1 = mechanical work put into dynamo.
W_2 = electrical „ given out by „
w_1 = mechanical „ taken out of motor
w_2 = electrical „ put into „
w_3 = „ available in „

$$E = V + Cr_1$$

$$E = V + C\,(r_1 + R)$$

$$e = V - Cr_2$$

$$C = \frac{E - e}{r_1 + R + r_2}$$

$$w_2 = CV \text{ watts}$$

$$w_3 = Ce = C\,(V - Cr) \text{ watts}$$

$$W_2 = CE \text{ watts}$$

Maximum possible electrical efficiency of system $= \dfrac{e}{E}$

Actual electrical efficiency $= \dfrac{w_1}{C(V + C(r_1 + R))}$

Actual mechanical efficiency $= \dfrac{w_1}{W}$

In order to get the greatest possible efficiency the value of e should be as large as possible, *i.e.*, the motor should run at as high a speed as possible, and in order to get as much power as possible with high efficiency E should be as large as possible.

The greatest amount of work is got out of the motor when it runs at such a speed that $e = \dfrac{E}{2}$. But in this case the efficiency is only 50 per cent., *i.e.*, only half the power given out by the dynamo generator is utilised in the motor. If the motor runs at a higher speed, the work it does becomes less, but its efficiency increases. When the speed becomes such that e nearly equals E, the work done is small, but it is nearly all being utilised.

Electric Light Cables.

TABLE 337.—ELECTRIC LIGHT CABLES: WEIGHTS, SIZES, AND RESISTANCES. (Silvertown List.)

Number of Wires in Strand.	Legal Standard Gauge of each Wire.	Diameter.				Equivalent to Solid Wires.				Weight of Conductor.		Resistance at 60° Fahr.	
		Of each Single Wire.		Of the Strand.		Diameter.		Area.		Per Statute Mile.	Per Kilometre.	Per Statute Mile.	Per Kilometre.
		Inch.	m/m.	Inch.	m/m.	Inch.	m/m.	Sq. In.	Square m/m.	Lbs.	Kilogrms.	Ohms.	Ohms.
1	22	·028	·711	...	...	·028	·711	·0006	0·397	12	4	72·52	45·06
1	21	·032	·813	...	...	·032	·813	·0008	0·518	16	5	55·53	34·50
1	20	·036	·914	...	...	·036	·914	·0010	0·656	21	6	43·87	27·25
1	19	·040	1·02	...	...	·040	1·02	·0012	0·810	26	7	35·53	22·07
1	18	·048	1·22	...	...	·048	1·22	·0018	1·167	37	10	24·68	15·33
1	17	·056	1·42	...	...	·056	1·42	·0024	1·588	50	14	18·13	11·26
1	16	·064	1·62	...	...	·064	1·62	·0032	2·075	65	19	13·88	8·624
1	15	·072	1·83	...	...	·072	1·83	·0040	2·626	83	24	10·97	6·816
1	14	·080	2·03	...	...	·080	2·03	·0050	8·242	102	29	8·884	5·520
1	13	·092	2·34	...	...	·092	2·34	·0066	4·287	135	38	6·718	4·174
1	12	·104	2·64	...	...	·104	2·64	·0085	5·480	173	49	5·257	3·266
1	11	·116	2·94	...	..	·116	2·94	·0105	6·774	215	61	4·225	2·625
1	10	·128	3·25	...	...	·128	3·25	·0128	8·302	262	74	3·470	2·156
1	9	·144	3·65	...	...	·144	3·65	·0162	10·50	332	93	2·742	1·703
1	8	·160	4·06	...	...	·160	4·06	·0201	12·97	409	115	2·221	1·380
3	25	·020	·508	·042	1·07	·034	·863	·0009	0·585	19	6	46·79	29·07
3	23	·024	·609	·051	1·29	·042	1·06	·0014	0·893	28	8	32·50	20·19
3	22	·028	·711	·059	1·50	·049	1·24	·0019	1·216	38	11	23·87	14·83
7	25	·020	·508	·060	1·54	·053	1·35	·0022	1·423	45	13	20·01	12·43
7	23	·024	·609	·072	1·83	·064	1·62	·0032	2·075	65	19	13·89	8·630
7	22	·028	·711	·084	2·13	·075	1·90	·0044	2·849	89	25	10·20	6·337
7	21½	·030	·762	·090	2·28	·080	2·03	·0050	3·242	102	29	8·893	5·525
7	20½	·033	·838	·099	2·51	·088	2·23	·0061	3·923	124	35	7·342	4·561

TABLE 337 (*continued*).

Number of Wires in Strand.	Legal Standard Gauge of each Wire.	Diameter.				Equivalent to Solid Wires.				Weight of Conductor.		Resistance at 60° Fahr.	
		Of each Single Wire.		Of the Strand.		Diameter.		Area.		Per Statute Mile.	Per Kilometre.	Per Statute Mile.	Per Kilometre.
		Inch.	m/m.	Inch.	m/m.	Inch.	m/m.	Sq. In.	Square m/m.	Lbs.	Kilogrms.	Ohms.	Ohms.
7	20	·036	·914	·108	2·74	·096	2·43	·0072	4·65	147	42	6·175	3·835
7	19	·040	1·02	·120	3·04	·107	2·71	·0089	5·77	182	52	5·002	3·1079
7	18	·048	1·22	·144	3·66	·128	3·25	·0128	8·30	262	74	3·473	2·158
7	17	·056	1·42	·168	4·27	·149	3·78	·0174	11·28	356	100	2·552	1·585
7	16	·064	1·63	·192	4·88	·171	4·34	·0229	14·73	465	132	1·953	1·213
7	15	·072	1·83	·216	5·49	·192	4·87	·0289	18·66	589	166	1·543	·9589
7	14	·080	2·03	·240	6·10	·213	5·41	·0356	22·98	727	205	1·253	·7785
19	20	·036	·914	·180	4·57	·159	4·03	·0198	12·74	402	113	2·261	1·404
19	19	·040	1·02	·200	5·08	·176	4·47	·0243	15·72	496	140	1·831	1·137
19	18	·048	1·22	·240	6·10	·211	5·35	·0349	22·66	715	201	1·271	·7897
19	17	·056	1·42	·280	7·10	·247	6·27	·0479	30·91	973	274	1·079	·6704
19	16	·064	1·63	·320	8·12	·282	7·16	·0624	40·25	1,270	358	·7154	·4445
19	15	·072	1·83	·360	9·14	·317	8·05	·0789	50·96	1,608	453	·5652	·3512
19	14	·080	2·03	·400	10·1	·352	8·94	·0973	62·77	1,965	559	·4579	·2845
19	13	·092	2·34	·460	11·6	·404	10·7	·1282	83·20	2,625	740	·3462	·2151
19	12	·104	2·64	·520	13·2	·458	11·6	·1647	106·3	3,354	945	·2709	·1683
37	16	·064	1·63	·448	11·3	·394	10·0	·1219	78·6	2,482	699	·3661	·2274
37	15	·072	1·83	·504	12·8	·443	11·2	·1541	99·58	3,142	885	·2892	·1797
37	14	·080	2·03	·560	14·2	·493	12·5	·1909	122·9	3,879	1,093	·2343	·1456
37	13	·092	2·34	·644	16·3	·566	14·3	·2516	162·6	5,130	1,445	·1772	·1101
37	12	·104	2·64	·728	18·4	·640	16·2	·3217	207·7	6,555	1,847	·1386	·0861
61	13	·092	2·34	·828	21·0	·728	18·5	·4162	268·7	8,477	2,389	·1072	·0666
61	12	·104	2·64	·936	23·7	·823	20·9	·5219	343·4	10,832	3,052	·0839	·0521

For insulating wires india-rubber is preferable to gutta percha, as the latter gets soft when heated. Vulcanized rubber may be raised 200° without becoming deteriorated.

A good electrical and mechanical insulation is given by covering the conductors with pure india-rubber, then vulcanized india-rubber, then india-rubber-coated tape, the whole being vulcanized together, and finally covered with braided tarred flax, and a coating of preservative compound. It is false economy to use any but the very best insulation. For low tension currents (up to 100 volts) the coverings should be such as to give an insulation to the wires of not less than 1,000 megohms per statute mile; for high tension currents (above 100 volts), the insulation should be as high as 5000 megohms per statute mile. It should be distinctly understood that should the cable whose insulation should normally be 5,000 megohms, test as low as 1,000 megohms, it would not do to use this for a low tension circuit, as the lowness of the insulation would not be due to the nature of the insulating material *but to a defect in it*, which defect would be almost certain to become worse in time. The cables should be tested in water at 75°, after immersion for at least 24 hours, a battery of about 400 to 500 volts being used. Tests as to insulation are perfectly useless unless carried out in a thorough manner.

According to the Board of Trade Regulations, the size of the conductor must be such that the maximum current which may have to pass does not exceed 2,000 ampères per square inch, the wire being of pure copper or its equivalent.

Calculation of Size of Conductor.

To calculate the size of conductor required, let—

p = greatest percentage of fall of E.M.F. along conductor which is to be allowed,

E = E.M.F. at dynamo terminals,

A = maximum number of ampères per square inch wire can safely carry,

c = current wire is required to carry;

then if length of circuit *exceeds*

$$\frac{p\text{E} \times 400}{\text{A}} \text{ yds.},$$

to calculate the sectional area (a) which the lead must have, use the formula

$$a = \frac{c}{p\text{E} \times 400}, \text{ sq. ins.}$$

If the length of the circuit is *less than*

$$\frac{p\text{E} \times 400}{\text{A}} \text{ yds.},$$

calculate from the formula $a = \frac{c}{\text{A}}$ sq. ins.

Telegraph and Telephone Wire.

TABLE 338.—RELATIVE DIMENSIONS, LENGTHS, RESISTANCES (AT 60° F.), AND WEIGHTS OF PURE SOFT COPPER WIRE.

(Glover.)

B.W.G. No.	Diam. Mils.	Area. Sq. In.	Lbs. per Foot.	Lbs. per Mile.	Feet per Lb.	Miles per Lb.	Feet per Ohm.	Ohms per Foot.	Ohms per Mile.	Ohms per Lb.
0000	454	·1619	·6239	3294	1·603	·0003036	19966	·00005008	·2644	·00008027
000	425	·1419	·5468	2887	1·829	·0003464	17497	·00005715	·3018	·0001046
00	380	·1134	·4371	2308	2·288	·0004333	13988	·00007149	·3775	·0001636
0	340	·09079	·3499	1848	2·858	·0005412	11198	·00008930	·4715	·0002552
1	300	·07069	·2724	1438	3·671	·0006952	8718	·0001147	·6056	·0004210
2	284	·06335	·2442	1289	4·096	·0007757	7814	·0001280	·6758	·0005242
3	250	·05269	·2031	1072	4·925	·0009327	6498	·0001539	·8125	·0007579
4	238	·04449	·1715	905·3	5·832	·001105	5487	·0001822	·9623	·001063
5	220	·03801	·1465	773·6	6·826	·001293	4689	·0002133	1·126	·001456
6	203	·03237	·1247	658·6	8·017	·001518	3992	·0002506	1·323	·002008
7	180	·02545	·09808	517·8	10·20	·001931	3139	·0003186	1·682	·003249
8	165	·02138	·08241	435·1	12·13	·002298	2637	·0003792	2·002	·004601
9	148	·01720	·06631	350·1	15·08	·002856	2122	·0004713	2·488	·007108
10	134	·01410	·05435	287·0	18·40	·003485	1739	·0005749	3·036	·01058
11	120	·01131	·04359	230·2	22·94	·004345	1394	·0007169	3·785	·01645
12	109	·009331	·03596	189·9	27·81	·005266	1151	·0008689	4·588	·02416
13	95·0	·007082	·02732	144·2	36·60	·006933	874·3	·001144	6·039	·04187

TABLE 338.—RELATIVE DIMENSIONS, LENGTH, RESISTANCES (AT 60° F.), AND WEIGHTS OF PURE SOFT COPPER WIRE—*continued.*

B.W.G. No.	Diam. Mils.	Area. Sq. In.	Lbs. per Foot.	Lbs. per Mile.	Feet per Lb.	Miles per Lb.	Feet per Ohm.	Ohms per Foot.	Ohms per Mile.	Ohms per Lb.
14	83·0	·005411	·02085	110·1	47·95	·009082	667·3	·001498	7·912	·07186
15	72·0	·004072	·01569	82·86	63·73	·01207	502·2	·001991	10·51	·1268
16	65·0	·003318	·01279	67·53	78·19	·01481	409·3	·002443	12·90	·1910
17	58·0	·002642	·01018	53·77	98·20	·01859	325·9	·003069	16·20	·3014
18	49·0	·001886	·007268	38·37	137·6	·02606	232·6	·004300	22·70	·5916
19	42·0	·001385	·005340	28·19	187·3	·03547	170·9	·005852	30·90	1·096
20	35·0	·0009621	·003708	19·58	269·7	·05108	149·4	·008427	44·49	2·273
21	32·0	·0008043	·003100	16·37	322·6	·06110	99·20	·01008	53·23	3·252
22	28·0	·0006158	·002373	12·53	421·4	·07981	75·95	·01317	69·52	5·548
23	25·0	·0004909	·001892	9·989	528·6	·1001	60·54	·01652	87·21	8·730
24	22·0	·0003801	·001465	7·736	682·6	·1293	46·89	·02133	112·6	14·56
25	20·0	·0003142	·001211	6·393	825·9	·1564	38·75	·02581	136·3	21·31
26	18·0	·0002545	·0009808	5·178	1020	·1931	31·39	·03186	168·3	32·49
27	16·0	·0002011	·0007749	4·092	1290	·2444	24·80	·04032	212·9	52·04
28	14·0	·0001539	·0005933	3·133	1685	·3192	18·99	·05267	278·1	88·77
29	13·0	·0001327	·0005116	2·701	1955	·3702	16·37	·06108	322·5	119·4
30	12·0	·0001131	·0004359	2·302	2294	·4345	13·95	·07169	378·5	164·5

TABLE 339.—HARD COPPER TELEGRAPH WIRE.

(Post Office Specification.)

Weight per Statute Mile.			Approximate Equivalent Diameter.			Minimum Breaking Weight.	Minimum Number of Twists in 3 Ins.	Maximum Resistance per Mile at 60° F.	Minimum Weight of each Coil of Wire.
Required Standard.	Minimum.	Maximum.	Standard.	Minimum.	Maximum.				
Lbs.	Lbs.	Lbs.	Mils.	Mils.	Mils.	Lbs.		Ohms.	Lbs.
100	97½	102½	79	78	80	330	30	9·1	50
150	146½	153½	97	95½	98	490	25	6·05	50
200	195	205	112	110½	113¼	650	20	4·53	50

The wire must be capable of being wrapped, in six turns, round its own diameter, unwrapped, and again wrapped in six turns round its own diameter in the same direction as the first wrapping, without breaking.

When aërial copper wires are used for telegraphic purposes, resin should be employed as a flux in making joints, and too much heat should not be applied, as it softens the wire and weakens its tensile strength at that point.

Samples taken from coils of the 800-lbs. wire should bear bending round a bar 2½ inches diameter without any signs appearing of the zinc cracking or peeling off; the 600-lbs. wire should similarly bear bending round a bar 2¼ inches in diameter; the 450-lbs. and 400-lbs. wire round a bar 2 inches in diameter; the 200-lbs. wire round a bar 1½ inches in diameter.

Iron Telegraph Wire

(page 630).

Test of Galvanizing.—Take samples from coils and plunge them into a solution of sulphate of copper saturated at 60°; allow them to remain in solution 1 minute, then withdraw and wipe clean. The galvanizing should permit of this process being 4 times performed with each sample without there being any sign of a reddish deposit of metallic copper on the wire, which would be the case if the coating of zinc were too thin.

See also page 633.

TABLE 340.—GALVANIZED IRON TELEGRAPH WIRE.

(Post Office Specification.)

Diameter.			Weight per Mile.			Tests for Strength and Ductility.						Maximum Resistance per Mile of the Standard Size at 60° Fahr.	Constant, being Standard Weight × Resistance.	Weight of each piece of Coil of Wire.		Weight of each Bundle.	
Required Standard.	Allowed.		Required Standard.	Allowed.		Minimum Breaking Weight.	Minimum Number of Twists in 6 Inches.	For Breaking Weight not less than	Minimum Number of Twists in 6 Inches.	For Breaking Weight not less than	Minimum Number of Twists in 6 Inches.						
	Minimum.	Maximum.		Minimum.	Maximum.									Minimum.	Maximum.	Minimum.	Maximum.
Mils.	Mils.	Mils.	Lbs.	Lbs.	Lbs.	Lbs.		Lbs.		Lbs.		Ohms.		Lbs.	Lbs.	Lbs.	Lbs.
242	237	247	800	767	833	2,480	15	2,550	14	2,620	13	6·75	5,400	90	120	90	120
209	204	214	600	571	629	1,860	17	1,910	16	1,960	15	9·00	5,400	90	120	90	120
181	176	186	450	424	477	1,390	19	1,425	18	1,460	17	12·00	5,400	90	120	90	120
171	166	176	400	377	424	1,240	21	1,270	20	1,300	19	13·50	5,400	90	120	90	120
121	118	125	200	290	213	620	30	638	28	655	26	27·00	5,400	40	65	80	130

Sags and Tensions for Suspending Wires.

The tension when the temperature is lowest, *i.e.*, when the strain is greatest, should not exceed ¼th of the breaking strain.

The sag varies with the material, but not with the gauge; the tension varies directly with the weight per foot of the wire.

$$d=\frac{l^2w}{8t};\quad d=\sqrt{\frac{3l(\mathrm{L}-l)}{8}};\quad \mathrm{L}=l+\frac{8d^2}{3l};\quad t=\frac{l^2w}{8d}.$$

where l = span;
w = weight of unit length;
d = sag (or dip);
L = length of wire in span;
t = tension;

also,

w for 400 lbs. iron = ·075758 lb. per foot.
„ 150 „ copper = ·028409 „ „
„ 100 „ „ = ·018939 „ „

and

Coefficient of expansion for iron = ·00000683 per deg. F.
Coefficient of expansion for copper = ·00000956 „ „

Table 341.—Sags and Tensions to be observed in erecting Wires at various Temperatures.

400-lbs. Iron Wire (No. 7½).

Span.	22° F. Low Winter Temperature.			40° F. Ordinary Winter Temperature.			58° F. Average Summer Temperature.			76° F. High Summer Temperature.		
	Sag.		Tension.	Sag.		Tension.	Sag.		Tension.	Sag.		Tension.
Yards.	Ft.	In.	Lbs.	Ft.	In.	Lbs.	Ft.	In.	Lbs.	Ft.	In.	Lbs.
100	3	1¾	270	3	9	227	4	3¼	200	4	8⅞	180
90	2	6⅝	270	3	1¾	219	3	2¾	190	4	0⅞	169
80	2	0¼	270	2	7⅛	210	3	0¾	178	3	5⅝	157
70	1	6½	270	2	1¼	198	2	6½	164	2	10⅞	143
60	1	1⅝	270	1	8	184	2	0¾	148	2	4¾	128
50	0	9½	270	1	3½	165	1	7¾	130	1	11¼	110

TABLE 341.—TABLE OF SAGS, ETC. (*continued*).

150-lbs. Hard-drawn Copper Wire (No. 12½).

Yards.	Ft.	In.	Lbs.	Ft.	In.	Lbs.	Ft.	In.	Lbs.	Ft.	In.	Lbs.
100	2	8	120	3	7	89	4	3⅞	74	4	11½	64
90	2	2	120	3	1	84	3	9½	69	4	4⅛	60
80	1	8⅜	120	2	6⅞	80	3	2½	64	3	8⅞	54½
70	1	3⅝	120	2	1¾	73	2	8⅝	57½	3	2½	49
60	0	11⅝	120	1	9	66	2	3⅛	51	2	8¼	43
50	0	8	120	1	4⅝	58	1	10	44	2	2⅜	36½

100-lbs. Hard-drawn Copper Wire (No. 14).

Yards.	Ft.	In.	Lbs.	Ft.	In.	Lbs.	Ft.	In.	Lbs.	Ft.	In.	Lbs.
100	2	8	80	3	7	59	4	3⅞	49	4	11½	43
90	2	2	80	3	1	56	3	9½	46	4	4⅛	40
80	1	8⅜	80	2	6⅞	53	3	2½	42½	3	8⅞	36
70	1	3⅝	80	2	1¾	49	2	8⅝	38	3	2½	33
60	0	11⅝	80	1	9	44	2	3⅛	34	2	8¼	29
50	0	8	80	1	4⅝	39	1	10	29	2	2⅜	24

Copper Wire.

Conductivity of Copper Wire.

$$\text{Percentage of conductivity} = \frac{l^2 \times 22{\cdot}61}{w \times k \times r}.$$

l = length of wire in feet.
w = weight of wire in grains.
r = resistance of wire in ohms.
k = temperature coefficient (p. 604).

Example.—The resistance of a copper wire 35 feet (l) long and weighing 297 grains (w), was ·932 ohm (r), the temperature being 68° F.; what was the percentage of conductivity of the wire?

From Table, p. 604, $k = 1{\cdot}015$, therefore

$$\therefore \text{Percentage of conductivity} = \frac{35 \times 35 \times 22{\cdot}61}{297 \times 1{\cdot}015 \times {\cdot}932} = 98{\cdot}6.$$

Resistance of Copper Wire.

Resistance per mile of pure soft copper wire at 60° F., d mils. in diameter $= \dfrac{54402}{d^2}$ ohms.

Resistance per mile of pure soft copper wire at 60° F. weighing w lbs. $= \dfrac{872{\cdot}2}{w}$ ohms.

Weight of pure soft copper wire 1 mile long having a resistance of 1 ohm at 60° = 872·2 lbs.

Length in yards of pure soft copper wire having a sectional area of a sq. ins. required to give a resistance of r ohms at 60° F. = $ra \times 41{,}161$. If

l = length of a wire.
a = sectional area.
d = diameter.
w = weight.
r = resistance.

$$r = \frac{l}{a}\kappa = \frac{l}{d^2}\kappa' = \frac{l}{w}\kappa''.$$

Where κ, κ', and κ'' are the resistances of a wire of unit dimensions. For pure soft copper at 60° F., if l is in feet, a in square inches, d in mils. ($\frac{1}{1000}$th in.) and w in grains (7000 grains = 1 lb.).

$$\kappa = \cdot 000008098,\ \kappa' = 10\cdot 311,\ \kappa'' = \cdot 2190.$$

The resistance of a copper wire increases about ·21 per cent. per 1° F. If

r = resistance at t° F.
R = „ „ T° F.
$R = r(1 + \cdot 0021(T - t))$ approximately.
„ $= r(1\cdot 0020935)^{T-t}$ more exactly.

Iron Wire.

Two qualities of iron wire are used by the Postal Telegraph Department for aërial line purposes, known as low resistance and high resistance wire. The low resistance wire may consist either of "special blend" iron, giving a mean resistance of 11·3 ohms per mile at 60° F. for the standard gauge of 171 mils. (No. 7½ B. W. G.); or of "charcoal" iron, giving under the same conditions a resistance of 11·2 ohms per mile. The high resistance wire which is more generally used (see Specification, page 630) of the same gauge has a mean resistance of 12·7 ohms per mile, but is cheaper in price. The low resistance iron is used for circuits over about 200 miles in length, its breaking strain is rather less than that of the high resistance wire.

1 foot-grain of pure iron has a resistance of 1·097 ohms at 0°C (32 F.).

1 ohm-mile (a wire 1 mile long, having a resistance of 1 ohm) of pure iron, weighs 4368·94 lbs.

Ditto, low resistance blend-wire weighs 4520 lbs.
Ditto, „ „ charcoal „ 4480 „
Ditto, high „ „ „ 5080 „

To determine the resistance R at a temperature t° F. that (r) at a temperature t° being known

$$R = r(1\cdot 0027)^{t_1 - t}.$$

Telegraphy.

Connections of Apparatus on the Morse System adopted by the Postal Telegraph Department.

SINGLE CURRENT SYSTEM.

DIRECT WRITER (Combination Instrument.)

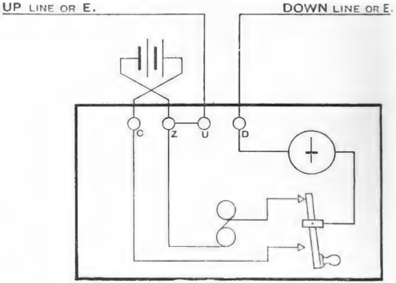
UP LINE OR E.
DOWN LINE OR E.
C
Z
U
D

FIG. 91.

DIRECT SOUNDER OR WRITER.

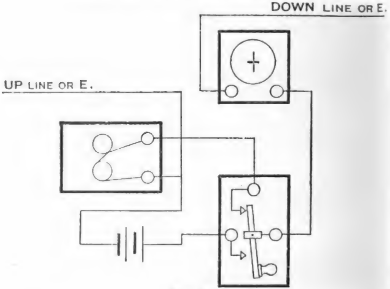
DOWN LINE OR E.
UP LINE OR E.

FIG. 92.

SOUNDER WITH RELAY.

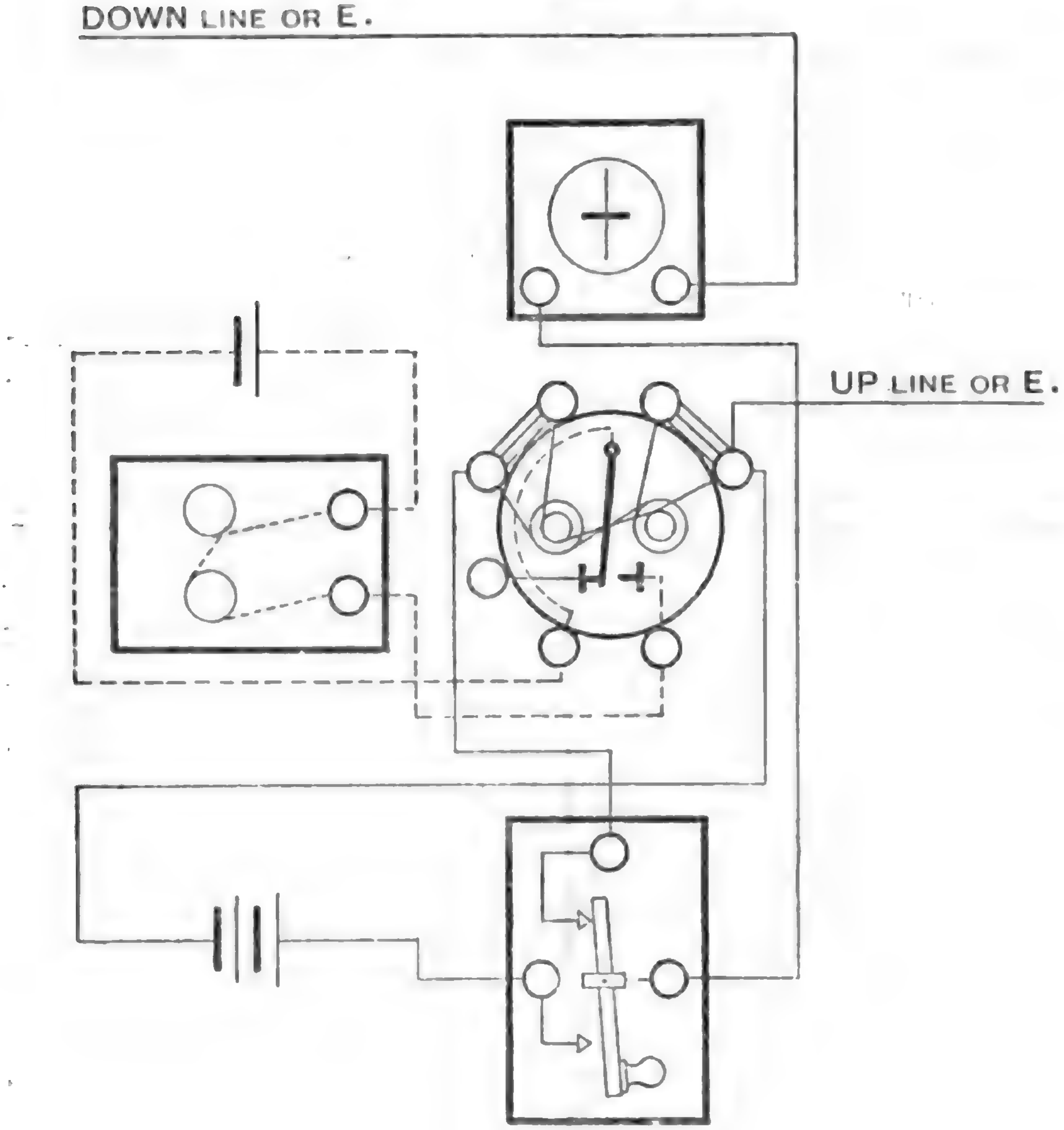
DOWN LINE OR E.
UP LINE OR E.

FIG. 93.

DIRECT WRITER. Duplex: with Switch.

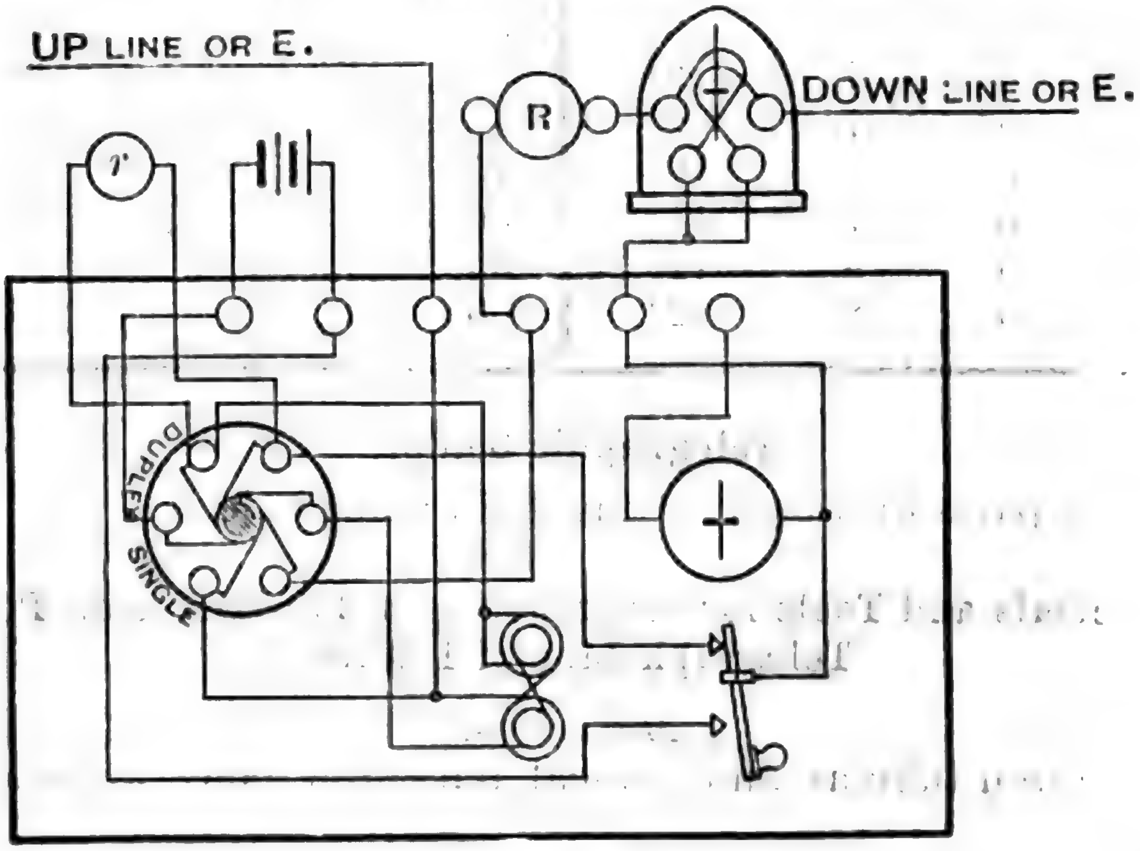
UP LINE OR E.
DOWN LINE OR E.
R
T
DUPLEX
SINGLE

FIG. 94.

All the systems require from 15 to 20 milliampères of current.

The Direct Writer Duplex system is suitable for circuits up to about 25 miles in length. The switch is employed for the purpose of changing the connections to the arrangement for ordinary working, should the insulation of the line become such as to render a proper balance by means of the Rheostat R difficult or impossible, and duplex working consequently impossible also. R is a fixed resistance equal as nearly as possible to the resistance of the battery.

TABLE 342.—TELEGRAPH POLES.

SIZES OF LIGHT POLES.				SIZES OF STOUT POLES.			
Length in Feet.	Diameter at Top. Inches.		Minimum Diameter at 5 Feet from Butt End. Inches.	Length in Feet.	Diameter at Top. Inches.		Minimum Diameter at 5 Feet from Butt End. Inches.
	Minimum.	Maximum.			Minimum.	Maximum.	
18	5	5¾	6½	18	5½	6½	7¼
20	5	5¾	6½	20	5½	6½	7½
22	5	5¾	6¾	22	5½	6¾	7¾
24	5	5¾	7	24	5½	6¾	8
26	5	6	7¼	26	5¾	7	8¼
28	5	6¼	7¾	28	6	7¼	8¾
30	5	6¼	8	30	6	7¼	9
32	5¼	6½	8¼	32	6¼	7½	9¼
34	5¼	6¾	8¾	34	6¼	7¾	9¾
36	5½	7	9	36	6½	7¾	10
38	5½	7	9¼	38	6½	7¾	10¼
40	5½	7¼	9¾	40	6½	8	10¾
45	5¾	7½	10½	45	6¾	8½	11½
50	6	7¾	11¼	50	7	8¾	12¼
55	6	8	12	55	7¼	9	13
60	6	8	12½	60	7½	9	13½

Telegraphic Solder.

Equal parts by weight of ingot tin and pig lead.

Materials and Tools for constructing a 300-Mile Iron Pole Telegraph Line of 1 Wire.

Materials.

6,000 iron tubular and conical telegraph poles attached to base pile for driving, the pole complete not weighing more than 100 lbs.; length over all when jointed 18 ft. Length of cast iron base pile about 4 ft., and tube about 14 ft. 6 in., with slit-joint between base pile and tube.

6,000 soft iron rings for caulking into base plate.

6,000 lightning rods, 18 ins. long, to surmount poles.

6,150 insulators, Cordeaux pattern.

4 Hand rammers, for driving base piles.

14 tons No. 14 hand-drawn copper wire, 103 lbs. to the mile, 340 lbs. breaking strain; resistance about 8 ohms per mile.

¾ cwt. best tin solder; 4 gals. soldering solution in gallon jars.

250 anchor plates, stay-rods, stay-wires, clips, &c., complete, for angle poles.

2½ cwt. No. 18 soft copper wire for binding wire to insulator.

½ cwt. No. 20 tinned copper wire for jointing line wire.

1 wire dynamometer vice for copper wire.

Construction Tools.

3 pairs small-draw vices and keys for No. 14 copper wire.
2 pairs devil's claws.
2 fire-pots.
6 8-in. cutting-pliers.
3 10-in. flat bastard files.
6 soldering-irons, large.
2 tool baskets.
12 lbs. lump sal-ammoniac.
3 large hammers.
2 sledge-hammers.
6 steel wedges.
1 2-ft. rule.
6 Picks, handled.
6 shovels.
6 spades.
3 jumpers.
2 iron punners, handled.
2 crow-bars, steel-pointed.
2 wire-drums and barrows, light and portable.
3 bill-hooks.
3 15-ft. wooden ladders.
3 American axes.
2 hand-saws.
2 saw-files.
2 screw-hammers.

Telephones.

Distance over which *good* speaking is possible :—

	KR.
Overhead copper wires	10,000
Cables and underground	8,000
Overhead iron wires	5,000

where KR is the product of the *Total* Inductive Capacity and the *Total* Conductor Resistance of the Line. If the value of KR exceeds the values given, the speaking commences to become difficult.

Through underground Wire No. 18 Copper and No. 7½ Gutta-percha, the *good*-speaking limit is about 36 miles.

If the working is carried on through a looped wire *with no earth used*, the value KR (*i.e.*, the capacity of the whole length of wire multiplied by the total resistance of the whole length of wire) must be divided by 4, to give the working value of the loop.

Lightning Conductors.

CODE OF RULES FOR THE ERECTION OF LIGHTNING CONDUCTORS (*Lightning Rod Conference*).

Points.—The point of the terminal should not be sharp, not sharper than a cone of which the height is equal to the radius of its base. But a foot lower down a copper ring should be screwed and soldered on to the upper terminal, in which ring should be fixed three or four sharp copper points, each about 6 in. long. It is desirable that these points be so platinized, gilded, or nickel-plated, as to resist oxidation.

Upper Terminals.—The number of conductors or points to be specified will depend upon the size of the building, the material of which it is constructed, and the comparative height of the several parts. No general rule can be given for this; but the architect must be guided by circumstances. He must, however, bear in mind that even ordinary chimney-stacks, when exposed, should be protected by short terminals connected to the nearest rod, inasmuch as accidents often occur owing to the good conducting power of the heated air and soot in a chimney.

Insulators.—The rod is not to be kept from the building by glass or other insulators, but attached to it by metal fastenings.

Fixing.—Rods should preferentially be taken down the side of the building which is most exposed to rain. They should be held firmly, but the holdfasts should not be driven in so tightly as to pinch the rod, or prevent the contraction and expansion produced by changes of temperature.

Factory Chimneys.—These should have a copper band round the top, and stout, sharp, copper points, each about 1 ft. long, at intervals of two or three feet throughout the circumference, and the rod should be connected with all bands and metallic masses in or near the chimney. Oxidation of the joints must be carefully guarded against.

Ornamental Ironwork.—All vanes, finials, ridge ironwork &c., shall be connected with the conductor, and it is not absolutely necessary to use any other point than that afforded by such ornamental ironwork, provided the connection be perfect and the mass of ironwork considerable. As, however, there is risk of derangement through repairs, it is safer to have an independent upper terminal.

Material for Rod.—Copper, weighing not less than 6 oz. per foot run, and the conducting of which is not less than 90 per cent. of that of pure copper, either in the form of tape or rope of stout wires, no individual wire being less than No. 12 B. W. C. Iron may be used, but should not weigh less than 2¼ lbs. per foot run.

Joints.—Although electricity of high tension will jump across bad joints, they diminish the efficacy of the conductor, therefore every joint, besides being well cleaned, screwed, scarfed, or riveted, should be thoroughly soldered.

Protection.—Copper rods to the height of 10 feet above the ground should be protected from injury and theft, by being enclosed in an iron pipe reaching some distance into the ground.

Painting.—Iron rods, whether galvanised or not, should be painted; copper ones may be painted or not according to architectural requirements.

Curvature.—The rod should not be bent abruptly round sharp corners. In no case should the length of the rod between two joints be more than half as long again as the line joining them. When a stringcourse or other projecting stonework will admit of it, the rod may be carried straight through, instead of round the projection. In such a case the hole should be large enough to allow the conductor to pass freely, and allow for expansion, &c.

Extensive Masses of Metal.—As far as practicable it is desirable that the conductor be connected to extensive masses of metal, such as hot-water pipes, &c., both internal and external; but it should be kept away from all soft metal pipes, and from internal gas-pipes of every kind. Bells inside well-protected spires need not be connected.

Earth Connection.—It is essential that the lower extremity of the conductor be buried in permanently damp soil; hence proximity to rain-water pipes, and to drains, is desirable. It is a very good plan to make the conductor bifurcate close below the surface of the ground, and adopt two of the following methods for securing the escape of the lightning to earth. A strip of copper tape may be led from the bottom of the rod to the nearest gas or water *main*—not merely to a lead pipe—and be soldered to it; or a tape may be soldered to a sheet of copper 3 ft. × 3 ft. and $\frac{1}{16}$th in. thick, buried in permanently wet earth, and surrounded by cinders or coke; or many yards of the tape may be laid on a trench filled with coke, taking care that the surfaces of copper are, as in previous cases, not less than 18 square feet. Where iron is used for the rod, a galvanized iron plate of similar dimensions should be employed.

Inspection.—Before giving his final certificate, the architect should have the conductor satisfactorily examined and tested by a qualified person, as injury to it often occurs up to the latest period of the works from accidental causes, and often from the carelessness of workmen.

Collieries.—Undoubted evidence exists of the explosion of fire-damp in collieries through sparks from atmospheric electricity being led to the mine by the wire ropes of the shaft and the iron rails of the galleries. Hence the head-gear of all shafts should be protected by proper lightning conductors.

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NOV 24 1915
JUL 6 - 1916
MAY 27 1918
MAY 28 1918
MAY 29 1918
MAY 30 1918
MAY 31 1918
JUN 1 1918
JUN 2 1918

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B'D AUG 26 1915